1972

Job shop automation.

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J O B S H O P A U T O M A T I O N

A Dissertation Presented

By

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Submitted to the Graduate School of the
University of Massachusetts in
partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

July 1972

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PREFACE

In an investigation of Job Shop Automation, a clear requirement exists to describe both a job shop and automation. Immediately, further questions occur concerning shop size, degree of automation, the difference between mechanization and automation, and the niche to be filled by the automatic factory. Such thoughts prompted this study. Its pursuit revealed a rather fascinating history and a few unexpected, stimulating possibilities in terms of future growth plus particular avenues for future exploration.

Purpose of this study. Much attention has been directed to automation in recent years. The term became popularly identified with mass production and large factories, perhaps because of associated concerns involving foreign competition, domestic productivity, unemployment, and inflation. The purpose of this study is to describe automation, to distinguish it from mechanization and the automatic factory, to give examples of successful application, and to forecast likely areas of future growth.

The availability of vast quantities of goods has tended to emphasize mass production and obscure the demand for discrete product models. The similar emphasis on declining per unit cost with increasing volume has suggested that job order operations are only profitable as special case situations. The electrical industry is, generally speaking, a job shop industry. Characteristically job shops are those whose output is low volume, high cost, and custom ordered. With the apparent consolidation of companies into even larger conglomerates, a question arises as to the future of the small shop. It appears from this study that an improving competitive opportunity exists for the small, selectively automated shop. The magnitude and extent of such opportunity can only be estimated.

What this study includes. First, an attempt is made to define the two key terms of "job shop" and "automation". Factors influencing job shop automation today are enumerated. These include development and growth trends of large companies, growth of technology, customer demand in volume and discrimination, labor and labor attitudes, and the estimated market growth for which major producers expect to complete.

In Chapter II, following a brief historical summary, the term "cybernetics" is defined in terms of its components of operations research and mechanization - automation. Some examples of applied operations research are given followed by criteria for instituting automation. A brief look at the leaders in the field, the motivating agencies, and typical savings from a single experiment conclude the chapter.

Chapter III explores the present industrial operating environment and its impact on the large company or larger plant. Four major areas of influence are: 1) Government or public policy such as antitrust, foreign trade, and import tariffs. 2) Community attitudes and expectations including local taxes and climate, geographical dispersion, level of experienced labor. 3) Labor and urban problems in terms of organization, minority groups, training, and physical plant adaptability. 4) Peripheral costs such as fringe benefits, fringe costs roughly related to size, and profit shortfall.

Chapter IV explores in some detail vendor practices of large manufacturers, and small shops and their acquisition of technology. Some criteria are established for measure and evaluation of business performance in terms of function and product concepts, portfolio management of the firms' assets and liabilities, and an equipment market forecast. Some cost comparisons are made for several classes of shops. Samples of opinion and examples of successful competition conclude the chapter.

Chapter V in addition to a summarization attempts an evaluation of job shop automation including limitations of application and opportunities for the small shop. An approach is suggested as to the source of both labor and venture for the small shop under varying economic conditions.

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CHAPTER I

INTRODUCTION

In the past decade, considerable attention has been given to automation by management, labor, and politicians. The rapid technological advances in a short time have their frightening aspects, but studies and attempts at regulation have often resulted in confusion rather than clarification. This thesis has a twofold objective. First, an attempt will be made to define the primary terms of job shop and automation, and to examine the current industrial operating environment. Second, several theoretical criteria will be used to evaluate application examples and draw some tentative conclusions for the future. As a prelude to detailed examination, this chapter looks broadly at the aspects of company growth, technology growth, labor, and market growth.

Definitions: Automation and Job Shop

Automation is defined as "a system or method in which many or all of the processes are automatically performed or controlled by machinery, electronic devices, etc".[1] Other definitions put more emphasis on method or purpose such as "those forms of technological change or mechanization which combine the elements of the computer, transfer devices, and automatic controls".[2] It is viewed more generally as "basically a means of freeing people from routine drudgeries".[3] For the pur-

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[1] Websters' New World Dictionary of the American Language, p 50.

[2] Dunlop, John T., editor, Automation and Technological Change, The American Assembly, p 4.

[3] Becker, Esther R. and Murphy, Eugene F., The Office in Transition, p 1.

pose of this study automation is defined as the use of automatic machines, including appropriate computer control, of two types:

1. Those which follow a set pattern without variation
2. Those which follow a prescribed pattern or set of conditions but have built-in mechanisms that permit modification of the pattern to a predetermined extent based on the interpretation of sensory information.

A job shop is a place where a particular piece of work is done by agreement for a price.[4] It is often thought of as a small, usually skillful, specialty shop operating to order and living frequently on a backlog of four weeks or less. Its chief customer attractions are fast response to an order, ability to accept and incorporate changes at any time during production, very few formal specification or documentation requirements, low cost.

Automation has been associated with large factories and mass production techniques, but many of the biggest plants in the electrical industry have operated as job shops. Through its increased flexibility, automation has permitted the mass production industries to gain the advantage of the job shop response to customer orders. It would seem logical that there are advantages to be gained from the marriage of the automated tool to the small job shop.

The rapid development of automated tools was made possible technologically by the transfer of World War II weapon techniques to civilian

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[4] Websters' New World Dictionary of the American Language, pp 405, 685.

applications. The sharp increase in labor costs and customer demand combined to make the sophisticated equipments economically feasible much more quickly than would have been possible earlier in the century.

Factors in Growth

Since the advent of the Industrial Revolution in the United States, the development of larger, more expensive machines resulted in a steady increase in the concentration of manufacturing facilities into larger plants and larger metropolitan areas. The giants appear in the industrially advanced societies. Of companies with a turnover of $700 million or more (in 1965) 272 are in the U.S., 54 in Britain, and 30 in Japan. In all the rest of the world, there are 99.[5]

The knowledge revolution also favors the large company. The stock of knowledge has probably doubled in the last 20 years. It will double at shorter intervals in the future. The new products resulting from an increase in knowledge represent a research and development program beyond the reach of small companies. Though one company may adopt a policy of following a competitor in marketing a new product, the choice is dependent on market conditions, not technological ones. If both are able to introduce products, the technology levels of the two are equal.

The concentration of economic power has no demonstrable or discernable limits at which, once fully under way, it would automatically cease.[6] Whether or not there is a limit to the size of plants or economic mass of firms, there is little doubt that the absolute size of plants

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[5] Corporations: Where the Game is Growth, Business Week, Sept. 30, 1967.

[6] Ibid.

will continue to increase in the current growth atmosphere.[7] Census Bureau figures on the value added in manufacturing - sales less cost of materials - show that in 1947 the 200 largest companies accounted for 30%. By 1963 the figure had risen to 41% and the 50 largest firms alone accounted for 25% of all contributed value. Annual sales of the top 20 manufacturers have risen from about $10.1 billion in 1926 to $107.9 billion in 1966.[8] It is obvious then that companies have become larger, that large companies will account for most research and development of new products, and that there is no automatic cessation or limit to their economic growth.

Consumer Pressures on Product Growth

The better educated, more discriminating customer, demanding products individually tailored to his needs, is forcing broader product lines on his suppliers.[9] True mass production of products such as valves and lamp bulbs concentrates production capacity around automatic or mechanized manufacturing lines. Economy of scale favors the large producer with very low per unit costs. The emergence of only three major lamp manufacturers illustrates the point.

Individually tailored products demand considerably more manufacturing operations. Economies similar to those of true mass production require much higher ratios of machine operating time to machine availability time than is possible with manually operated machine tools.

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[7] Buckingham, Walter S., Automation: Its Impact on Business and people, p 27.

[8] Corporations: Where the Game is Growth, Business Week, Sept. 30, 1967.

[9] Ibid.

The broader product scope precludes the hard tooling techniques which produced the needed efficiencies for mass produced products.

Automated tools, or more generally, computer assisted manufacturing enabled companies to meet the expanded individualized demand of their customers by making possible the conversion of mass production to high speed job shops responding to individual orders "no two of them alike". The larger companies spent the research and development money and reaped the immediate benefits. Though many new plant sites were established in the U. S. in the post World War II years, the pattern was very similar to earlier growth waves. In the past 200 years since the emergence of the factory system, the development of that system has been mostly evolutionary. Only in the last twenty years have principles begun to develop which furnish answers that are known to be optimal to problems of limited scope.[10]

Labor

The attitude of the factory worker is currently a somewhat unknown factor in the production equation. There is no longer any real doubt that automation creates jobs.[11] But it often creates new kinds of jobs. It is difficult for workmen, trained in a particular skill, to retrain successfully for the new jobs created by automation.

The worker in todays' large factory tends to be surrounded by machines, not people. Often the lack of other workers nearby plus the complexity of the automated machine he is tending, cause a sense of over-

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[10]Buffa, Elwood S., Modern Production Management, pp 11 - 12.

[11]Readers' Digest Almanac and Year Book, pp 411 - 440.

whelming responsibility and job frustration.

The large producer has to some extent succeeded too well. For 200 years he has increased his capital investment, increased the size of his plant and labor force to supply his expanding market. Continuing work specialization satisfactorily met competitive challenges before 1930. The emergence of the professional manager and the construction of new plants after 1946 took advantage of new labor sources and broke the founders' old homestead tie. As the limit of the labor market approached, automation was a logical step. The machines now available displace men. They perform functions with greater repetitive accuracy than men can.

After World War II, many new plants were established to serve new market centers and relieve critical labor problems. Computer assisted manufacture provided the large firm with a broad product line responding to the new customer demands. A bigger market for the small shop also emerged. Automated output depends more on the tool than on the operator. If the small shop has the same tools as the large one, the technologies of the two shops with respect to those tools, are equal. If the technology of two competitors is equal, competition is on price. Here, the small shop can compete because many elements of its cost are lower than those of the large firm.

CHAPTER II

TECHNICAL CONSIDERATIONS

It is the purpose of this chapter to explore the conditions necessary for automation. A method of manufacture is largely determined by (a) type of production demand, and (b) relative cost. The desirability of using a scientific approach for investigating manufacturing conditions has become more apparent as production complexity increases. Today, manufacturing methods are reduced to three options: mechanization, automation, or an automatic factory. Automation is selected only when type of demand and costs are favorable. Following a brief review of U.S. production history, examples are given showing application of the scientific approach to production problems. Next, automation criteria are presented followed by examples of successful application.

History

On May 1, 1798, Mr. Eli Whitney submitted a proposal to the United States Government to furnish 10,000 stands of arms over the next two years at a total price of $134,000. One stand of arms consisted of a musket, bayonet, ramrod, wiper and screwdriver and was priced at $13.40. Delivery was to be completed by September 30, 1800. Though progress payments were arranged, production experience was so poor that the payments were totally inadequate. Final delivery was not made on the contract until 1808; Whitney had to be rescued from bankruptcy several times; and the whole affair came to be rather dubiously regarded at the time.

Mr. Whitney, however, accomplished three items of utmost significance:

1. He proved the feasibility of part interchangeability, a

matter of tactical as well as economic significance.

2. He induced, however painfully, long-term financing on a scale and of a method hitherto unknown.
3. He developed trained factory labor on the basis of operations rather than skills, though he complained that they required too much supervision.[1]

The results were an increase in firearms manufacturers from one firm in 1798 to 140 in 1810 with a capacity increased from less than 5000 to 40,000 stands of arms per year; and a tangible demonstration that the principle of production organization, later to be known as work simplification, could provide an economical challenge to Europe's manufacturing superiority. The principle established by Mr. Whitney survived until the present day and only began modification after a century of pure application.

The major advantage of work simplification is minimized training. Because the worker need only learn how to perform one part of the job, he can be trained quickly compared to the former practice of a four to twelve year apprenticeship. In addition, many people can learn to perform a few operations well while relatively few can become true craftsmen. Mr. Whitney introduced the country to a planned reduction of labor skills, lower per unit labor costs, higher production volume, and lower prices for more available goods. In short, the same formula in 1800 as 1970 with the major differences those of technology, tools, and general education level.

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[1] Armed Forces Management, Vol. 16, No. 5, February 1970

During the greater part of the nineteenth century, only two sources of factory power were available; water and steam. Little good quality iron was produced until after mid-century. Steel could not be satisfactorily made and brass was relied on where great stress was encountered until Krupp steel cannon passed the rigorous test of 1870-71. The post-Civil War expansion of the United States was carried forward largely on steel rails furnished by Krupp and while the world was learning, copying, and competing for markets with Krupp steel, a new major piece in the industrial power structure appeared: The electric motor. It provided a non-seasonal, highly versatile, efficient, stable energy source. Its subsequent application solved the production problem.

The development of the electric motor, supported by means of generating and transmitting electric power economically, removed its restriction to heavy jobs and allowed it to take on delicate work at high speed. The breakthrough into light industry allowed full application of work simplification techniques and caused the entrenchment of the principle among industrial planners and the manufacturing engineering profession.[2] The electric motor freed machine location from the line shaft drive and permitted layout for maximum floor space utilization. In addition, the increased productivity available brought more tasks together under one roof.

The electric motor also made practical expanded applications of the conveyor belt and the assembly line. The versatility of electricity enabled work simplification principles to be maximized. Whether end

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[2] Dunlop, John T., editor, <u>Automation and Technological Change</u>, The American Assembly, pp 29-30.

products were large or small, manufacture was accomplished by concentrations of similar machines feeding manufactured parts through accumulation points to assembly lines. The assembly lines comprised a series of stations where each worker was trained to perform a limited number of operations.

This mass production supplied the high volume output of goods containing interchangeable parts. Low cost was achieved by the simplified training for operation proficiency rather than skill proficiency, reduction of total skills required, and concentrations of those needed skills into particular areas from which the whole plant effort could benefit. Large plants were able to expand the number of models produced and thus begin to supply the response benefits of the job shop to the low per unit cost of mass production. Perhaps the most visible illustration of this point is the automobile industry. The 1930's saw founder Henry Ford tenaciously retain his one model concept to his distinct competitive disadvantage. Totally eliminated were some prestigious cars such as Chandler, Pierce-Arrow, LaSalle and others. While the method was advantageous to the manufacturer in terms of minimum skill emphasis, low training costs, and relatively low wage rate; its success depended on the ability to move proper quantities of material frequently and economically. Strict adherence to work simplification techniques places all screw machines in one area, milling machines in another, sub assembly line oriented to assembly lines and these pointing to test areas and the shipping dock. If the output is several models of refrigerator relays, the whole operation including engineering can be handled in perhaps 5000 square feet; but if the output is several models of B-52 aircraft, the area gets huge.

At various times in the past, workers have revolted against being supplanted by machines. While no one today pretends to prefer a manual tool to a powered one, the concern centers about a controlled balance between progress and employment. A recent presidential advisory committee defined its purpose as that "which will encourage essential progress in the form of automation and technological change, while meeting at the same time the social consequences such change creates.[3] The second concern is by far the more difficult to understand, predict, and satisfy. Here it will only be possible to mention items of social consequence while concentrating on the aspects of technological progress associated with automation of the job shop.

Cybernetics

Cybernetics is defined broadly as dealing with the comparative study of complex electronic machines and the human nervous system.[4] Industrially, cybernetics is divided into the areas of Operations Research and Mechanization - Automation. This approach addresses itself to man - machine relationships and operates within the prime capitalist objective of profitability.

Operations research. The first area of cybernetics, operations research, has as its object the search for patterns rather than discrete elements of a system. If the operational parameters governing the patterns can be determined, it may no longer be necessary to worry about

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[3] Dunlop, John T., editor, Automation and Technological Change, The American Assembly, pp. 35-36, 166.

[4] Websters' New World Dictionary of the American Language, p 188.

manipulation of discrete elements.[5] That is, having become familiar with molecular behavior of gasses, a gas can be manipulated and controlled by the action of a piston in a chamber. It is not necessary to manipulate molecules. It would seem likely that production problems would succumb to a similar approach.

Mechanization - automation. To determine when and how to apply automation, it is necessary to look carefully for patterns. The system parameters of the problem rather than the product require thorough examination. Two examples illustrate the technique. A portion of General Electrics' distribution transformer business, at the time of the study, represented an output of 3000 to 5000 units per week, an active manufacturing roster of 12,000 models, a cost range of $150 to $5000 per unit and a weight range of 170 to 16000 pounds. These statistics superficially argued for continuation of job shop production. Analysis of detailed information displayed in chart form led to revision of the initial opinion. Looking specifically at the 15KVA rating, it became apparent that models with a primary voltage rating below 5000 volts used one basic set of parts while those rated 5000 to 15000 volts used another. A second break appeared in ratings about 15KV, but this break was not nearly so marked as that at 5KV and quantities about 15KV rating were relatively small. The pertinent parameters were those associated with KVA size, voltage rating and particular mechanical or electrical features rather than with models as had been originally assumed.[6] If the business represents a hundred

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[5]Hurni, Melvin L., The Next Step In Management An Appraisal of Cybernetics, pp 2-6.

[6]Ibid, p 20.

model numbers of 15KVA transformers with primary voltage below 5000 volts and scheduled production of 500 per week, it appears that five (5) possible like units per week is the expected average. This certainly is a job shop quantity. But, if all 15KVA transformers with 5000 volts and below primary use the same magnetic core, the same internal support structure, the same tank parts, and the same secondary bushings; the resulting quantities of 500 identical cores, 1000 support structures and subassemblies suggest economies of volume production, the advantages of engineering design modification for work simplification, and broad simplifications of indirect labor procedures such as ordering, planning, scheduling, and material flow.

The same principle was applied to medium motors. Because of the effect of speed of rotation on physical size for a given horsepower, and customer specifications for things like shaft length and mechanical connections; it was considered likely that patterns would be more difficult to discern. A sample of orders was examined with the following results:

90% of the orders were filled by
- 50% of the model numbers
- 40% of the wound stators
- 38% of the stator windings
- 22% of the frames
- 21% of the frame castings
- 18% of the stator punchings
- 37% of the rotor assemblies
- 20% of the shafts
- 20% of the rotor bodies
- 19% of the rotor punchings
- 20% of the end shields and fittings
- 16% of machined end shields
- 19% of end shield castings[7]

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[7] Hurni, Melvin L., The Next Step in Management An Appraisal of Cybernetics, pp 29-32.

Here again, the economies are obvious when it is recognized that 90% of the orders can be filled with about 20% of the total anticipated parts. In this case 80% of the parts used for only 10% of the production were obscuring or preventing employment of advanced methods. This investigation also resulted in broad simplification and reorganization of production facilities. Basically manufacturing was concentrated on 10 punchings, 21 castings and 34 machined frames. The rotor shop was concerned with 25 punchings, 92 rotor bodies, and 64 shafts. The assembly shop, receiving this standard output from manufacturing, needed only to apply the procedural differences required to supply stator and rotor windings to conform to customer orders. Both manufacture and inventory control improved. Customer order identification was not assigned until assembly began. The remaining 10% of the orders were handled in a special job shop, but here also an unforeseen benefit accrued. Approximately 7% of the special orders could be filled by modification of standard parts and only 3% required special basic parts.

These examples show the value of applying a scientific approach to production problems. Any production system will benefit from the application of operations research even though the resultant conclusion is to make no change in present methods. The two examples given argue strongly for mass production which would mean mechanization rather than automation. What then makes automation attractive in terms of producing goods?

Automation criteria. The application of cybernetics to production problems should first result in a thorough analysis, a search for and evaluation of patterns. Secondly, a decision should result in some form of three basic options:

1. Continue present manufacturing method implementing improvements discovered by the study.
2. Produce families of parts through use of replanned hard tooled conventional machines or process type automated systems to gain the advantages of large quantity repetitive production.
3. Automate through application of numerically controlled machines.

Automation is imperative only where it is economical. Numerically controlled machines or computer assisted manufacture can pay off on the following types of work:

1. Where positioning time is large compared to machining time.
2. Where a large amount of fixturing is required to hold size, shape, or uniformity.
3. Where a long tool procurement cycle is encountered.
4. Where the complexity of the task makes the possibility of human error high.
5. Where there is a possibility of design change.
6. Where the number of pieces in the lot is small.
7. Where a large number of set ups would be required on separate machines.
8. Where frequent inspection is required to check machining accuracy.
9. Where high cost materials are used in fabrication and where labor content is high making any scrap costly.
10. Where lead time is important for competitive reasons.
11. Where large numbers of tool changes are required.

12. Where families of parts are produced requiring similar but not identical machine operations.
13. Where parts are to be assembled by aligning holes, mating surfaces, selective fit, etc.
14. Where parts of wide variation, function, or dimension are required, space consuming inventory can be eliminated.
15. Where multiple, decentralized production sites are engaged in producing identical parts requiring exchange of tooling or manufacturing data.[8]

Jobs having large quantity, repetitive parts should - except for overriding circumstances - be planned for hard tooled, conventional machines.

Automation through the use of numerical control or computer assisted manufacture contributes flexibility, not speed, to manufacture. An NC machine cuts no faster than a manually operated one. The NC advantage occurs in speeding up work or tool transfer time. Set-ups, positioning, mating of parts, tool changes, and inspection all involve some function of transfer time. Eight of the fifteen criteria touch on this item. Major cost benefits of automation may be expected to accrue from reducing transfer labor through automatic programmed steps built into the machine control.

Broad Industrial Trends

Research and development expenditures by industry give evidence of product and market trends. Certainly strong emphasis on research and development demands strong response from those groups responsible for

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[8]Knauss, W. P. Jr., Numerical Control Lecture Series, p 11.

manufacturing the developed products. Table 1 shows recent expenditures by industry.[9] While no single reason explains levels or trends of research spending, the table discloses some significant items:

1. Government contribution is significant in those industries allied to Aerospace or NASA.
2. Smaller industries are planning distinct increases in laboratory facilities.
3. The machinery industry is spending on a par with Aerospace and second only to chemicals.

The machinery builders are responding with equipment to supply the needs of large manufacturers for an increasing volume of custom built products. The automobile industry claims that customer options result in nearly every car being earmarked for an individual. The industry is now "custom-making cars, though on a mass production basis".[10] Westinghouse Electric Corporation and General Electric Company, two giants representing the tremendous product span of the electrical industry are in a similar situation. Westinghouse manufactures and sells more than 300,000 variations of 8000 basic products.[11] General Electric produces over 200,000 different products in 242 plants 155 locations throughout the world.[12]

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[9] R & D Looms Big in Fiscal Budgets, Business Week, May 13, 1967.

[10] Detroit Tools Up Drive to Cut Costly Callbacks, Business Week, February 4, 1967.

[11] Westinghouse Plugs In, Business Week, June 17, 1967.

[12] General Electric Company A Brief History, and Highlights of Its Present Operations, p 4.

	$ Millions				New Labs & Equipment $ Millions		U.S. Support of Industrial R&D $ Millions	Research carried out abroad $ Millions
Industry	1965	1966	1967	1970*	1966	1967*	1966	1966
Iron & steel	$ 131	$	$	$	$ 17	$ 31	$ 0.5	$ 0.4
Nonferrous metals	85				16	25	6.4	3.0
Machinery	1,129	1,287	1,416	1,742	125	123	244.5	47.6
Electrical machinery & Communications	3,167	3,325	3,558	4,163	81	107	1,995.0	12.0
Aerospace	5,120	5,734	6,193	8,546	82	123	5,160.6	0.0
Autos & other transportation equipment	1,238	1,250	1,275	1,352	25	59	312.5	237.5
Fabricated metals and ordnance	145	181	206	241			18.1	6.0
Professional & scientific instruments	387	495	535	663	102	91	158.4	7.4
Chemicals & allied products	1,377	1,473	1,561	1,842	144	137	176.8	44.2
Paper & allied products	76	82	88	104	18	21	0.1	0.4
Rubber products	166	169	176	208	12	14	15.2	2.0
Stone, clay & glass	119	129	151	205	44	73	5.2	4.9
Petroleum products	435	452	488	571	26	35	65.5	13.1
Food & kindred products	150	165	186	221	48	59	3.3	17.3
Textile mill products & apparel	34	40	44	54	14	12	0.2	0.8
Other industries**	438	447	483	589	24	29	245.9	4.5
Total	$14,197	$15,457	$16,605	$20,792	$778	$939	$8,408.2	$401.1

* Estimates

** Includes tobacco, lumber & wood products, furniture, printing & publishing, miscellaneous manufacturing, mining, utilities and railroads:

Data: McGraw-Hill Economics Dept.

TABLE 1

Applications of Criteria

Industry generally, responding to marketplace conditions and applying the fifteen criteria, is moving quickly to automation in the form of numerically controlled, computer assisted machines. The aerospace industry was the first user and is still the largest because of expensive materials involved, complex shapes required, and the benefits to be derived in reduced fixturing, set-up time, and inspection plus great improvement in repeatable accuracy.[13] Table 2 shows General Electric Company investment in Numerical Control Machines and Controls as of March 1970. Cost of the machines varies from a $5000 Aging Rack to a seventy-two foot Ingersol Gantry at $3.1 million.[14] Table 3 shows the annual average per unit cost of the equipment listed in Table 2.

The greatest concentration of NC equipment within General Electric is at Evendale, Ohio (163) where aircraft engines and parts are manufactured. Most locations have 10 to 30 NC machines installed and these run the gamut of products including locomotives, various types of control, industrial turbines, military electronics, and ordnance. As might be expected, products representing high volume standardized parts such as lamps, distribution assemblies, power capacitors, tubes, and circuit protective devices are on the low end of the NC equipment spectrum.[15] These rely on improved hard tooling as suggested earlier in this chapter. The data in Tables 2 and 3 show that types of machines in terms of unit cost and total amount invested in automation in any year are de-

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[13]New Generation Machine Tools Evolving, Aviation Week and Space Technology, April 15, 1968.

[14]General Electric Numerical Control Association Report, Spring 1970.

[15]Ibid.

GENERAL ELECTRIC COMPANY INVESTMENT IN MACHINES AND CONTROLS

In Millions

Year Manufactured	No. of Machines	Cumulative No. Machines	Cost of Machines	Total Company Plant & Equipment Additions	Cumulative Cost of Machines
1957	4	4	$ 287 000	$153 600 000	$ 287 000
1958	15	19	1 471 000	104 100 000	1 758 000
1959	26	45	1 808 000	97 000 000	3 566 000
1960	17	62	1 340 000	166 200 000	4 906 000
1961	50	112	2 566 000	179 700 000	7 472 000
1962	35	147	3 163 000	173 200 000	10 635 000
1963	48	195	6 050 000	149 200 000	16 685 000
1964	68	263	6 055 000	237 700 000	22 740 000
1965	125	388	14 067 000	332 900 000	36 807 000
1966	159	547	14 872 000	484 900 000	51 679 000
1967	163	710	17 515 000	561 700 000	69 194 000
1968	101	811	27 486 000	514 700 000	96 680 000
1969	50	861	10 706 000	530 600 000	107 386 000

TABLE 2

AVERAGE UNIT COST OF GENERAL ELECTRIC NC MACHINE

YEAR	NUMBER OF MACHINES	AVERAGE UNIT COST
1957	4	$ 71 750
1958	15	98 067
1959	26	69 538
1960	17	78 824
1961	50	51 320
1962	35	90 371
1963	48	126 042
1964	68	89 044
1965	125	112 536
1966	159	93 535
1967	163	107 454
1968	101	272 139
1969	50	214 120

TABLE 3

termined on criteria other than a ratio to the amount of plant and equipment investment itself. Figure 1 shows a graph of total plant and equipment expenditures, NC machine expenditures, and average per unit cost verus time in years. There is some evidence of a time-displaced correlation between total plant and equipment additions and cost of numerical control equipment. This is not unexpected since NC equipment is part of the total. The average per unit cost behaves differently and, except for a rise during a distinct prosperity cycle, shows evidence of different governing criteria. This also is to be expected if the fifteen criteria are in fact measures of when to automate.

A universal measure for justifying appropriation of purchase funds is return on investment. Table 4 shows the machine utilization guide in current use by the General Electric Company.[16] The relation-

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[16] _General Electric Numerical Control Association Report_, Spring 1970.

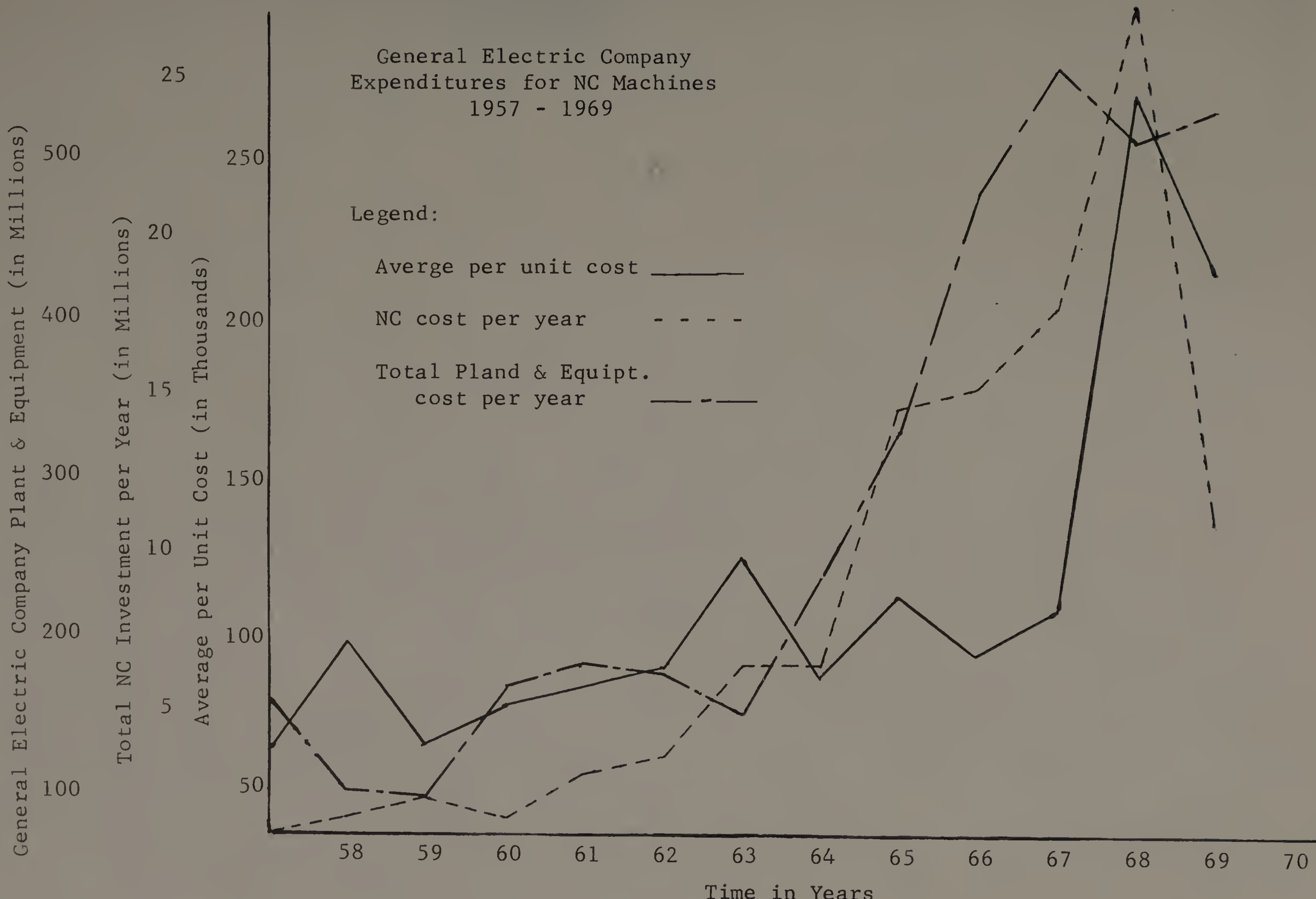
General Electric Company
Expenditures for NC Machines
1957 - 1969
Legend:
Averge per unit cost
NC cost per year
Total Pland & Equipt.
cost per year
General Electric Company Plant & Equipment (in Millions)
100
200
300
400
500
Total NC Investment per Year (in Millions)
5
10
15
20
25
Average per Unit Cost (in Thousands)
50
100
150
200
250
58
59
60
61
62
63
64
65
66
67
68
69
70
Time in Years

FIGURE 1

EQUIPMENT UTILIZATION GUIDE

Machine Cost	Shifts	Hr/Yr Machine Available	Hr/Yr Operator Available	% Util.	Hr/Yr Machine Producing
$ 50 000	5 days 2 shifts	4 176	3 800	85	3 200
$ 100 000	5 days 3 shifts	6 264	5 400	85	4 600
$ 300 000	6 days 3 shifts	7 296	6 500	80	5 200
$1 000 000	7 days 3 shifts	8 760	7 600	80	6 100

TABLE 4

ships listed are those believed required for adequate return on investment. The difference between machine availability and operator availability represents operator absenteeism for both planned and unplanned reasons. The utilization percent applies to the time the operator is available. As the table shows, overtime is considered necessary to get adequate return on the investment. Figure 2 is a representative graph showing where NC machines are best applied when production quantity is considered. The upper economic lot size is 50 to 100 pieces although other considerations can increase this upper limit considerably.[17] The lower limit depends on initial programming costs which in turn depend on the complexity of the piece to be manufactured and the availability of appropriate "canned" programs.

As was predicted, with the average per unit cost running in excess of $110,000 over the thirteen year period described in Tables 2 and 3, the large manufacturers accounted for virtually all the NC machines purchased and spent the necessary development money to acquire

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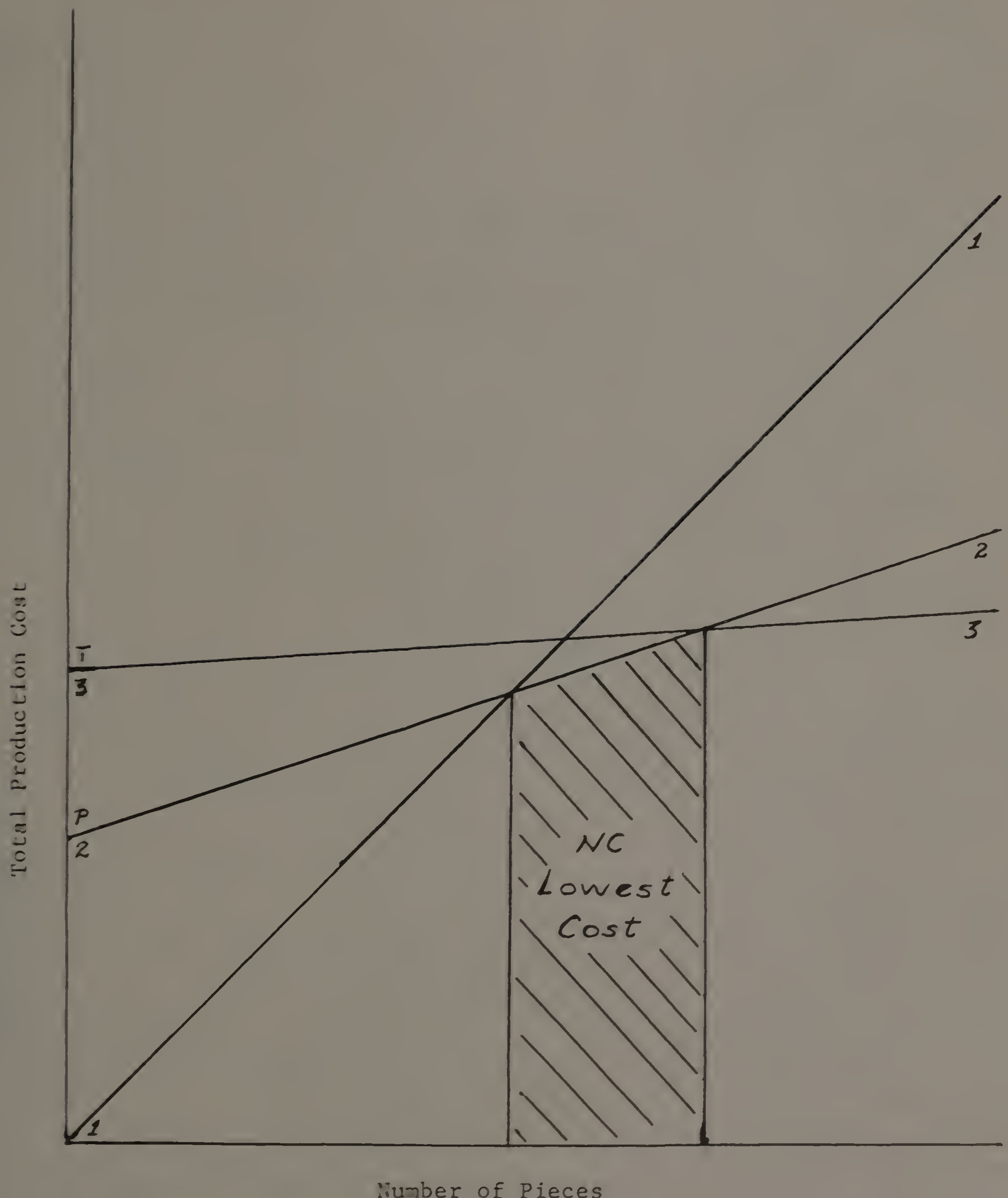
[17]Knauss, W. P. Jr., Numerical Control Lecture Series, p 17.



1. Conventional machining. No tooling.
2. NC Machining. P is programming cost.
3. Hard tooling. T is initial tooling cost.

FIGURE 2

knowledge and technique. Once the tape control established its supremacy over the original template - stylus method, people within the industry visualized direct computer links from a central processor to remote machines perhaps hundreds of miles away.[18] Except for special demonstrations in the early 1960's (General Electric operated machines in their Waynesboro, Va. plant from a computer center in Schenectady, N.Y.) the evolution of NC applications has taken a much more conservative route.

Punchpress application. The specific requirement to be met is that automation must be economical. While general guidelines as represented by Table 4 and Figure 2 are useful, almost every reference to application guidelines indicates wide latitude in practice. Typical savings are shown below for an A-15 Wiedematic Punch Press,[19] a tape controlled machine:

Reduction in direct labor	$33,250 per year
Reduction in shift premiums	3,700 " "
Reduction in scrap and rework	1,500 " "
Increase due to programming maintenance and other Indirect Manufacturing Expense	(5,500) " "
	$32,950 Net Savings

Installed cost of the machine was $130,000. Production time comparison for five typical parts is as follows:

	A-15 Wiedematic	Manual Machine
Set up	0.112 hours	0.501 hours
Operation	0.849 hours	2.199 hours

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[18] Personal experience - 1953-1960.

[19] Data provided by Mr. W. A. Copley in an interview with the author at Waynesboro, Va. on July 13, 1966.

Stated times represent an output of just over 1000 parts. Contrary to the suggested operating schedule in Table 4, this machine was operating no more than two shifts, and often only one, at the time the comparison was made. Additional benefits not included in the stated savings were an improvement in physical inventory and reduction in factory working drawings.

Automated test equipment. Automation of test equipment can appropriately utilize the same rationale as automation of production equipment when it successfully meets the criterion of economy. Missiles and rocket systems no doubt account for the great bulk of the applications, but significant savings can also be achieved in prosaic production. General Electric invested $15,000 in automated test equipment for their Mark Century line of machine tool controls. In two years, savings of $50,000 were realized. Original test time was 100 manhours per control. Automated testing forecast a reduction to 40 manhours while actual experience proved to be 16 manhours per control. Quality showed a marked improvement in the same period as measured by reduction of rework time, recorded errors and installed operating reports. At the beginning of the program in March 1963 errors ran 7.1%. In June of 1964 errors were 3.18% and by June 1965, 2.35%. Error percentages are based on recorded extra work time over planned. During this period sales volume of the product more than doubled.[20]

Summary

Automatic tooling has existed not only in concept but also in practice since 1800. The Jacquard loom employed the idea that punched

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[20]Data provided by Mr. J. M. Hoylman in an interview with the author at Waynesboro, Va. July 13, 1966.

cards linked with cords could automate weaving in textile mills. When 400 such looms in 1804 grew to 11,000 in 1812 anguished cries of impending disater to thousands of workmen were heard.[21]

Whitney, Howe, Colt, and others developed and expanded mass production through interchangeability of parts, organization of the labor force to operation rather than craft, innovative financing, and combination of resources into larger companies. The combined resources enabled the large companies to organize research and development for new products and techniques, but the two significant technological developments making possible manufacturing breakthrough were: 1) the successful use of electricity in the dynamo of the late nineteenth century, and 2) the development of sophisticated control systems including computers after World War II.

The application of the scientific method to production systems determines the optimum use of automation. Cost savings from this flexible system are achieved by the successful marriage of the two technological milestones mentioned above. Programmed machines now perform transfers of tools or work formerly done by men. The machines improve on the men by a factor of 3 or better as the examples showed.

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[21] Automation and Education, Tooling and Production, September 1968.

CHAPTER III

ENVIRONMENTAL FACTORS

Social consequences of technological change have received increasing attention since the 1930's when it was recognized that the rate of technological change was increasing fast enough to cause social impact well within one lifetime. As mentioned in Chapter II, such changes can only be listed here, but social concern is now beginning to have a recognized impact on technological progress at least in short term direction. Thus the large companies, who were able to concentrate resources and afford research, and who have increased their share of value added to manufacturing by nearly 4 to 1 since 1947, are now faced with the threat of legislation to break them up. At the same time they are faced with higher community taxes where they have been in residence for many years. Profits as an industry objective are coming under increasing criticism. Acquisition of land for modernizing operations is subject to public opposition if it affects housing units. Such contention affects business decisions and can therefore affect competitive conditions. In this chapter, pertinent concerns are listed under broad headings with an attempt to give opposing views and some assessment of impact. The categories selected are:

1. Public policy and economic environment
2. Community attitudes
3. Labor and urban problems
4. Peripheral costs

Public Policy and Economic Environment

On a national scale, concern for size is reflected in antitrust legislation and administration. Though monopoly in some form has existed in every known civilization it has also been a matter of contention.[1] The salt monopoly of France is credited with being a major grievance in the chain of abuses leading to the revolution of 1789.[2] Legislation in this country has been relatively recent. The Sherman and Clayton Acts were concerned primarily with restraint of trade through various types of agreements and marketing arrangements. More recently, in such decisions as the so-called Tobacco Case (United States vs. American Tobacco Co., 324 U.S. 836) the opinion rendered was based on the premise that it is illegal to possess the means for establishing a monopoly or unreasonably restraining competition <u>even though the power had not been exercised</u>![3] Such concern has not prevented three great merger waves from sweeping the country since the legislation first appeared nor did it prevent the suspension of the antitrust laws in the 1930's in favor of the NIRA (a form of planned production). When the NIRA was found to be unconstitutional by the Supreme Court in the Schechter Case (295 U.S. 495), many companies who had entered into the trade associations fostered by NIRA found it very difficult to discontinue all of the activities thus begun.[4] Industrial leaders often find antitrust questions difficult to deal with because the rules, laws, and interpretations seem to change with little regard to precedent.

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[1] <u>Trust Regulation</u>, American Peoples Encyclopedia, Vol. 19.

[2] Ibid.

[3] Ibid.

[4] Ibid.

Not only does the emphasis on individual company practices change but also the direction and emphasis of the administrators. Donald F. Turner, former Chief of the Justice Department Antitrust Division attempted to provide durable guidelines for the types of mergers which were lawful under antitrust statutes. The guidelines provided a philosophy, so far missing from antitrust actions, which said that bigness would not be penalized per se nor would small enterprises be protected per se but that guilt would be established based on acquisition or sharing of monopoly power. That is, violation of the Sherman Act would exist if a company shared with one or two other firms in an industry the power to raise prices above a competitive level.[5] Traditionally crusading antitrusters were sharply critical of Mr. Turner for allowing the giant corporations to continue to expand their share of the nations wealth. See Figure 3 and Table 5. A case in point was that the Pure Oil-Union Oil of California merger went unchallenged though it created a company whose combined assets were \$1.7 billion while at the same time the attempted merger of Pennzoil and Kendall Refining Company was challenged. The latter two had combined assets less than 10% of Pure-Unions'; however, Pennzoil and Kendall, though small in nationwide ranking, were first and third among companies producing, purchasing, and refining Penn-grade crude. If these two companies merged they would produce or purchase 61% of all Penn-grade crude. Pure and Union, on the other hand while ranking in the top 200 industrials, were not competitors since Pure's market was

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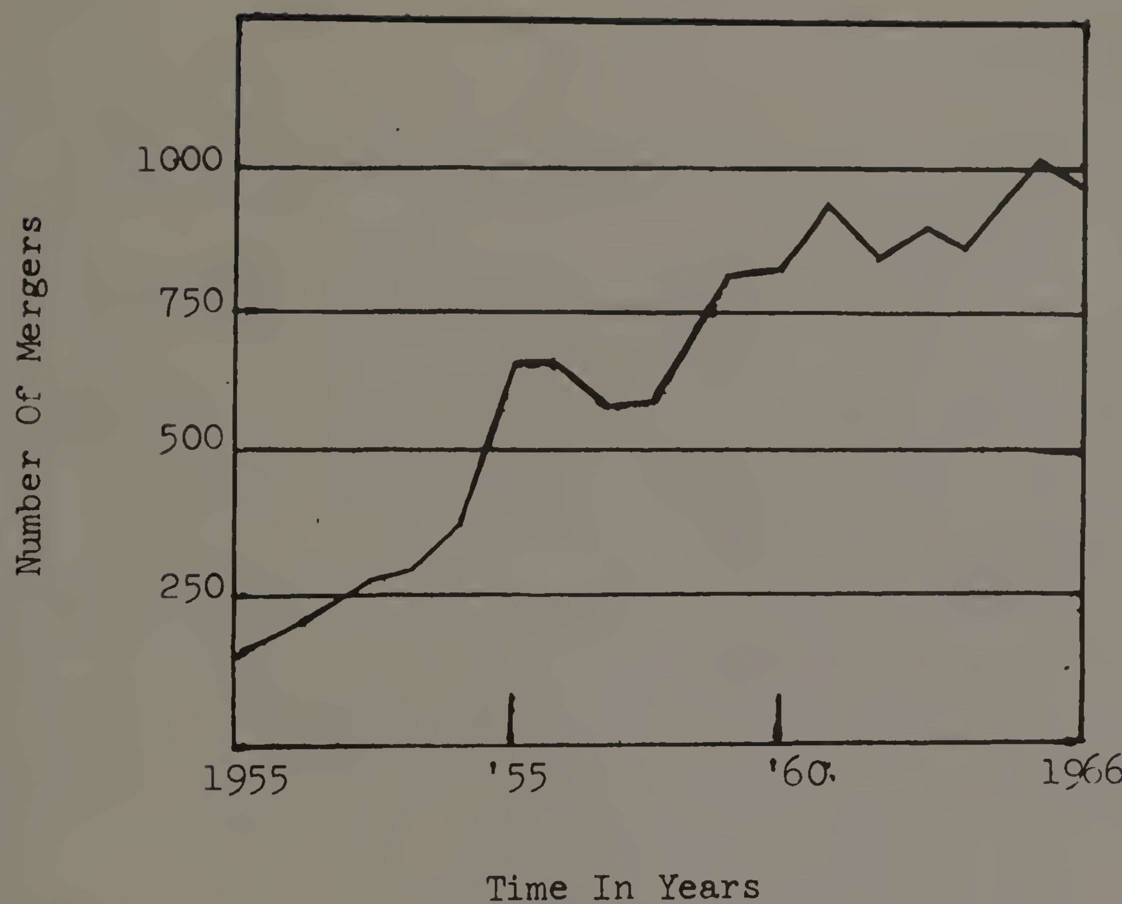
[5] Taking the Crusade out of Antitrust, Business Week, May 20, 1967.



Data: Federal Trade Commission

FIGURE 3

Corporations	Per cent of total U.S. manufacturing assets 1950	1965
5 largest	9.6%	11.8%
20 largest	20.7	24.6
100 largest	38.6	45.4
200 largest	46.7	55.4

Data: Federal Trade Commission

TABLE 5

in the Southeast and Midwest while Union sold its products on the West Coast and the Rocky Mountains.[6] Additional merger trend data is given in the appendix.

Mr. Turner believed that additional legislation was needed to challenge comglomerates.[7] The Federal Trade Commission, however, launched a full scale investigation of the conglomerate movement the week following Mr. Turners' resignation. FTC Chairman Paul R. Dixon felt that Section 7 of the Clayton Act already outlawed mergers which might tend to restrict competition, that this section applied to conglomerates, and that no additional legislation was required. Significantly, the government's limited success in attacking conglomerate mergers has been scored by the FTC.[8]

The Justice Department according to Richard McLaren, Assistant Attorney General in charge of the Antitrust division, is trying to prevent further economic concentration in the U. S. The business view, supported by a spokesman for the Commerce Department, is that growth or bigness is a reward for efficiency and that agreements between U. S. firms and those abroad protect U. S. business in a world market. U. S. business is already facing increasing restrictions abroad. If the Government is successful, foreign competition in domestic markets will increase. Such an event could cut domestic profits and jobs and adversely affect U. S. balance of payments.[9] Targets are large companies.

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[6] Taking the Crusade out of Antitrust, Business Week, May 20, 1967.

[7] Probing the New Giants, Business Week, July 13, 1968.

[8] Ibid.

[9] Trustbusters' Challenge U.S. Firms' Dealings with Concerns Abroad, Wall Street Journal, July 30, 1970.

Community Attitudes

The question of taxes involves both community attitude and economic environment. Corporate income tax is relatively stable regardless of geographic location within the U. S. This is due partly to the fact that the federal government receives 77% or more of the total of all collections, local, state, and federal.[10] Local revenues are almost entirely dependent on property taxes. Certainly taxes of all sorts have risen alarmingly since 1913 because of the demand of increased services on the part of citizens.[11]

Of the three major ideologies of taxation:

Ability to Pay
Barriers and Deterrents
Equity

property taxes are most closely identified with Barriers and Deterrents since an increase in demand for services requires a direct increase in levy on land occupied. While it may be argued as Adam Smith did that this type of tax was "more or less unthrifty taxes that increase the revenue of the soverign, which seldom maintains any but unproductive labourers; at the expense of the capital of the people, which maintains none but productive."[12], a property tax has been supported for local needs as one which closely relates cost, collection, and spending.[13] The main

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[10] Taxation, American Peoples Encyclopedia, Volume 18.

[11] Ibid.

[12] Eisenstein, Louis, The Idealogies of Taxation, p 60.

[13] Tax Policy League, Property Taxes, pp 3-21.

concern over corporate taxes is when do they begin to deter investment.[14] It is almost impossible to determine who bears the burden of corporate taxes and what affect they are likely to have on economic growth.[15] Experts seem able to agree only that at some point taxes levied on business or individuals will become barriers to expansion initiative and deterrents to investment.

As a trend to geographical dispersion is noted, it can be inferred that if taxes in one locale are lower than another, certainly the location with the lower tax is a competitively advantageous one in which to do business if other factors are approximately equal. An illustration is the situation in western Massachusetts. The low margin textile and leather industries having left the state have not been successfully replaced by other enterprises. The disease seems to be spreading to the electrical manufacturers.

Recently, General Electric Company officials invited the Pittsfield (Mass.) City Council to discuss government-imposed burdens which aggravate cost disadvantages for businesses operating in Massachusetts. The chief burden subject to city control is the local property tax. Between 1966 and 1971 General Electric city taxes doubled which added a million dollars to the company's cost of doing business. In the same time period, however, the portion of total Pittsfield taxes paid by General Electric rose from 10% to 13%.[16] The Pittsfield tax rate was

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[14] Paul, Randolph E., Taxation for Prosperity, p 345.

[15] Corporation Tax, The American Peoples Encyclopedia, Volume 6.

[16] GE News, Volume 58, No. 12, March 24, 1972.

$39.70 per thousand dollars of valuation in 1966 and $56.60 in 1971.[17] The company claimed pollution control costs as well as local and state levies are higher in Massachusetts than in other parts of the country.[18] Since 1953 portions of General Electric's transformer manufacture, a traditional Pittsfield business, have moved to Georgia, Louisiana, and North Carolina.

At the local level, issues become personal. Size of both community and industry is a major factor, although it would appear to be relative rather than absolute size. Whether in a friendly or antagonistic local atmosphere, the larger industries are those selected to make contributions while the smaller ones occupy more nearly the role of an individual. Obviously, the bigger plants have a larger stake in all aspects of the community and they must expect, like prominent individual citizens, to respond to more community demand. It is not suggested here that this represents an inequity. It suggests, however, that there may be some optimum relative size for a plant in a community and that the weighted community factors could influence decisions on the part of a firm against growing in size at that place when traditional manufacturing rationale, efficiency, and economy (particularly short term) might otherwise favor local growth.

Often, local considerations and reactions seem difficult to predict accurately. There may be strong local demand for things such as

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[17] GE Backs Nutman Project in Plea for Tax Sharing, The Berkshire Eagle, March 21, 1972.

[18] Ibid.

modernized production equipment or increased electric power capacity. Yet immediate strong opposition will develop if a nuclear plant is suggested to supply the requested electrical capacity or if land and housing acquisition is begun to make room for modernization. Regardless of the merits of the respective arguments, the delays thus injected will often make a geographical move preferable to local expansion.

Labor and Urban Problems

Several points are worth mention in considering labor and urban problems.

1. The industrial cost squeeze
2. Worker motivation in automated environment
3. Stable minority jobs, area labor pools and urban centers

The industrial cost squeeze. The cost-price squeeze, aggravated by increased foreign competition is translated into a more widespread concern about productivity in the United States. The price of labor as a major element of cost requires increased productivity to avoid inflation and maintain a competitive position for U. S. industry in world markets. The nation is committed to high employment levels though the definition of the term has varied from 5% unemployment as reasonable in 1960 to the same level as unacceptable in 1970. As employers struggle to keep costs under control, some rise in the unemployment index is inevitable because of past rises in unit labor costs. At the same time, part of the recent rise in the index has been caused by the re-entry into the labor force of women looking for jobs to supplement the family income which has been hit by inflation.[23] The public has higher need expectations and service requirements which tend to change and expand with the ability of industry to serve them. This shift in social expectations and consumer demand has led to a significant growth in the services - government sector of the economy. By 1967 this sector had increased to 56% of the working population versus industry at 39% and agriculture at 5%. In the years 1969 and 1970, durable goods prices increased about 7.2% while medical care went up 13% or 3.6% and 6.5% annually respectively. In the same period, construction labor costs increased 9.1% annually while state and local taxes increased 15.2% per year.[24]

Increases in cost of living generated by the services - government sector create pressures for higher wages and salaries in the manufacturing sector. The non-postponable costs of services (medicine, education, garbage collection, utilities) appear at the industrial bargaining tables. Nor will the growth in the services - government area aid or compensate in any way in world markets because the output of this sector cannot be exported to pay for an ever increasing stream of manufacturing imports as reflected by the international balance of payments. U. S. manufacturers can attempt to counter these forces with substantial investments in equipment and product development, either by further capital investment domestically for improved manufacturing yields, or by securing manufacturing facilities offshore. This situation results in the anamoly in the United States of a sustained high level of capital in-

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[23]Borch, F. J., Productivity and the Nation's Economy, Statement before the Joint Economic Committee, Congress of the United States, July 8, 1970.

[24]Ibid.

vestment in the face of mounting idle manufacturing capacity and unprecedented money costs.[25] Idle capacity and profit margin erosion demonstrate competitive restraint of prices in the manufacturing sector while prices in the services sector remain relatively unchecked. (See Table 6) Certainly the purchase of offshore manufacturing facilities will have an adverse effect on employment in the United States. Also taking construction labor productivity as an example, when a U. S. company can erect two similar nuclear power plants, one in this country and one in Japan, with the Japanese installation requiring 1,150,000 <u>fewer</u> skilled manhours due to the relative productivity of the respective work forces alone; it is understandable that offshore manufacturing facilities are being sought.

The concern about the current profit shortfall has been voiced by such eminent economists as Dr. Frank E. Highton, Manager of Labor Economics Research, General Electric Company and Dr. George L. Perry of Brookings Institution. The concern is not so much that profits declined from 1969 to 1970 since 1970 was a year of general decline, but rather that profits declined between 1966 and 1969. The latter condition represented an imbalance of economic forces which is further strengthened by the other unusual condition of increasing or even accelerating wage increases at a time when unemployment is rising.

While concerned about the pressures and dangers from the government - services sector of the economy, industry is forced to compete by improving productivity. In an address to the 1971 Personnel Conference, Mr. Jerome M. Rosaw, Assistant Secretary of Labor suggested "pro-

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[25]Borch, Fred J., <u>Productivity and the Nation's Economy</u>, Statement before the Joint Economic Committee, Congress of the United States, July 8, 1970.

TABLE 6

Some Aggregate Measures Of The U.S. Economy

	Consumer Price Index (1967=100)	Compensation Of Employees ($ Billion)	Average Gross Hourly Earnings	Net Corporate Profits ($ Billion)	Profits As % Of Sales (Mfg)
1946	58.5	117.9	N.A.	15.5	N.A.
1947	66.9	128.9	1.13	20.2	N.A.
1948	72.1	141.1	1.23	22.7	N.A.
1949	71.4	141.0	1.28	18.5	5.8
1950	72.1	154.6	1.34	24.9	7.1
1951	77.8	180.7	1.45	21.6	4.8
1952	79.5	195.3	1.52	19.6	4.3
1953	80.1	209.1	1.61	20.4	4.3
1954	80.5	208.0	1.65	20.6	4.5
1955	80.2	224.5	1.71	27.0	5.4
1956	81.4	243.1	1.80	27.2	5.3
1957	84.3	256.0	1.89	26.0	4.8
1958	86.6	257.8	1.95	22.3	4.2
1959	87.3	279.1	2.02	28.5	4.8
1960	88.7	294.2	2.09	26.7	4.4
1961	89.6	302.6	2.14	27.2	4.3
1962	90.6	323.6	2.22	31.2	4.5
1963	91.7	341.0	2.28	33.1	4.7
1964	92.9	365.7	2.36	38.4	5.2
1965	94.5	393.8	2.45	46.5	5.6
1966	97.2	435.5	2.56	49.9	5.6

TABLE 6 (Continued)

	Consumer Price Index (1967=100)	Compensation Of Employees ($ Billion)	Average Gross Hourly Earnings	Net Corporate Profits ($ Billion)	Profits As % Of Sales (Mfg)
1967	100.0	467.2	2.68	46.6	5.0
1968	104.2	514.1	2.85	48.2	5.1
1969	109.8	564.2	3.04	48.5	4.8
1970	116.1	599.8	3.22	44.4	4.0

N.A. = Not Available

Source: Economic Report of the President

Productivity Increase per year

1965	3.4%
1966	4.0%
1967	2.1%
1968	2.9%
1969	0.8%
1970	1.5%

Year	Jobless Rate %	Hourly Rates % Increase/Yr.	Unit Labor Costs	Unit Profits
1965	4.6	4.1	0.7	8.0
1966	3.8	6.9	2.8	1.4
1967	3.8	5.8	3.7	-4.6
1968	3.6	7.3	4.9	-0.5
1969	3.4	7.2	6.5	-3.7
1970	4.9	7.2	6.2	-10.1

(% change from preceding year)

TABLE 6 (Continued)

Electrical Industry Wage Performance Comparisons

Year	1950	1970	Mid 1971
Consumer Price Index (1967=100)	72.1	116.1	119.2
Electrical Av. Gross Hourly Earnings	$1.444	$3.29	---
Total Private Av. Gross Hourly Earnings	$1.335	$3.23	---
Consumer Costs of: (1967=100)			
Electricity			110.4
Washing machines			108.4
Refrigerators			107.5
Ranges			109.8
Electric drills			107.2
TV sets			100.3
Radios			99.1
Tape recorders			95.7
Wholesale Price Index (1957-59=100)			117.8
Electrical machinery and equipment			110.1
Industrial chemicals			98.8
Household appliances			96.0
Home electronic equipment			77.3

Source: Bureau of Labor Statistics

ductivity bargaining is a realistic means of combining efficiency with economic advances for the worker". Conference speakers suggested that the pressures which impede worker productivity must be recognized; there must be a real commitment by top management to the idea that worker satisfaction is essential to increase productivity; and that better techniques must be found to motivate the worker to bring his creativity, ingenuity, effort and concept of excellence back to his job.[26]

Worker motivation in automated environment. Worker motivation has long been recognized as a needed element for successful production. The new element is the recognition that increaed wages alone no longer constitute sufficent motivation when the worker is being exposed to swift technological and social changes.

The problem is one of recognizing the dignity of the individual worker and tapping his intelligence for the total job while attracting the minorities into the industrial labor market to achieve a share of the 30 billion dollar consumer demand thirty years hence. This must all be done at a cost that will not dangerously aggravate the "profit shortfall". The skilled and semi-skilled worker is pushed by automation, the reduced wage differential between himself and the unskilled worker, and the shift of job responsibility. As factories mechanize or automate, workers become fewer and lose the sense of being part of a group. Often this means that one worker now controls whole processes where he formerly contributed with others to an operation. The individual often feels that an

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[26] Management News, Volume 44 No. 4, April 1971.

almost overwhelming increase in responsibility has been thrust on him.[27] Often, the sense of being subject to closer personal supervision is also heightened. Significantly, power plant workers reacted most favorably as a group to automation. Where before they were scattered throughout the powerhouse taking necessary routine data, automation has brought them together in a control center where automatic supervisory instruments record conditions continuously. In an emergency, the group in the control center can act together where each once had to act alone. Here, shared responsibility is increased while the sense of individual demand has lessened.[28]

Increasing attention is now being given to utilizing the workers' group effort to improve a job or product. This could be a very important move which would result in greatly improved worker attitudes. Mr. E. A. Cafiero, Group Vice President - U. S. and Canadian Automotives, of Chrysler Corporation says, "We recently started introducing into our plants what we call our Job Enrichment Program. Our thinking is that the man who does a job all day long should know more about that job and how to improve it than anybody else. So we are going to the people on the job to get their ideas, and to let them follow through and put their own ideas into action.

"At Chrysler we believe our people have something to say so we are giving them a chance to speak up. We think it's going to pay off for

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[27] Dunlop, John T., editor, Automation and Technological Change, The American Assembly, pp 43-47.

[28] Ibid.

us in better quality, better operations, and more satisfied employees."[29]

General Electric has conducted some formal research into this aspect of worker motivation. Dr. Herbert H. Meyer, Manager of Personnel Research for the company reported the results of a project carried out at the company's Court Street Plant in Syracuse, New York. The premise of the experiment was that if factory workers had a chance to make more personal contribution in their work, they would also give more personal commitment. Twelve welders were offered and accepted a chance to participate in the experiment. In addition to the welding work they normally performed, the group also were offered complete responsibility for all planning, scheduling, and control functions. They were to plan the job, sketch tooling and fixtures, and communicate directly in other areas when necessary. They were given help from the experts who normally worked in the area but only at their request. Dr. Meyer commented "The men showed enthusiasm for their work. Management showed trust in them and respect for them, and they reacted in a responsible and conscientious manner." One direct result was a 50% savings in machine shop overhead plus overhead reductions in the planning and tooling areas. Though consulting services of a psychologist were made available during the project, Dr. Meyer added "---the intensive guidance of a highly trained psychologist is not required to make substantial changes in the way the roles of hourly employees are defined in order to enhance their motivation. It does require considerable courage on the part of the managers involved."[30]

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[29] Cafiero, E. A., in Chrysler Corporation Report to Shareholders, July 19, 1971.

[30] Relations Review No. 71-4, February 22, 1971, General Electric Company

It seems reasonable to construe these efforts as attempts to capture for the large manufacturer the inherent advantage of a small shop; direct communication and direct involvement in the total job.

Stable minority jobs, area labor pools, and urban centers. These particular elements are separate aspects of a larger concern. One can hardly be discussed without involving another. Except for isolated instances of large companies attempting to build or operate model cities, business reaction to the urban problem has been that it will concentrate on those areas where it can best apply its developed expertise; creating jobs and offering management advice to "ghetto capitalists". Seeking and training needed labor has led to hiring people over 65[31] on flexible work schedules, increasing numbers of working wives and mothers (more than double those in the work force in the 1940's),[32] providing courses for prison inmates[33] and some rather stimulating, innovative testing and training techniques for the hard core unemployed who often cannot read English at the sixth grade level.[34] In addition to the attractive market potential represented by all forms of the peripheral labor resource, large employers recognize that they cannot run away from the problem of

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[31] Wall Street Journal, November 2, 1970.

[32] More Moms on Payroll, Business Week, December 31, 1966.

[33] Computer Programming Course Conducted by G.E., Ordnance Dept., News, November 1, 1965.

[34] Tests That Sharpen Work Skills, Business Week, January 4, 1969.

urban decay. Each newly hired disadvantaged worker contributes an estimated $10,000 a year to the gross national product, pays $227 a year in federal and state taxes, enjoys additional purchasing power of $3,400 a year, and decreases welfare payments by $1,300.[35]

The various worker training enterprises and "ghetto capitalist" ventures which began with suitable fanfare have enjoyed rather spotty success. International Harvester failed completely in their first "New Start" program, but made a success of the second effort.[36] Labor Secretary Shultz seemed to say that the government also was convinced of the necessity of a new second approach when he announced the closing of 59 out of 160 training centers in 1969.[37] A number of companies have opened plants in Negro ghettos. Control Data Corporation located a 300 employee plant in Washington, D. C., Lockheed began a 300 employee facility in the Watts area of Los Angeles, Fairchild Hiller Corporation opened a 90 employee plant in Washington, D. C., and Avco Economic Systems Corporation is operating in Boston's Roxbury district. These companies report varying degrees of success, but main concerns are high absenteeism (often 20%) and high employee turnover (125 employees have quit at Fairchild's 90 employee plant).[38] But E G & G decided to quit in 1970 after a two year effort in Boston which lost $500,000 during its period of operation.

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[35] G.E. Faces Urban Crisis, Relations Review No. 69-17, May 26, 1969.

[36] How to Turn Dropouts into Steady Workers, Business Week, August 31, 1968.

[37] Job Corps Gets a Working Over, Business Week, April 19, 1969.

[38] New Plants Dot the Black Slums, Business Week, March 22, 1969.

About 60 workers were employed there.[39]

The "ghetto capitalist" ventures have enjoyed varying degrees of success depending on the business segment selected, the type of support required and obtained, and quality of employees. Industry seems to have been the most successful in carrying out, in a search for qualified labor, a training and recruiting program for labor segments heretofore considered marginal to totally unemployable. It is a tragedy that in the event of a business downturn virtually all of the newly trained workers, who are just beginning to contribute as part of the stable work force, will face layoff. There is no doubt that the hard core job holder will be affected.[40] Certainly some of these workers become discouraged and leave the work force.[41]

Peripheral Costs

Costs termed fringe benefits are a distinct competive concern. For a number of reasons associated with attracting, training, and motivating labor, these costs appear to be a greater burden on the large plant than on the small shop. General Electric released the following data about its Pittsfield businesses in 1971:

1. Wages and benefits up 24% since 1968
2. Material costs up 10% in the same period
3. Selling prices below those of the early 1950's

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[39] Wall Street Journal, April 1, 1970.

[40] Bumps for Hard Core, Business Week, March 22, 1969.

[41] Warped Statistics, The Wall Street Journal, January 8, 1971.

4. Absenteeism (except for vacation period) between 5% and 6%

5. Three-phase pad mounted transformers are being moved to the new Shreveport, Louisiana plant which is designed to produce at lower manufacturing costs

6. Employment reduced by about 10% in 1969-70 while medical benefit expenses rose 27%

7. A 1971 forecast reduction of an additional 700 employees would be accompanied by an increase of $11,000 in vacation expense

8. Medical expenses on a cost per employee basis have behaved as follows:

1968	$89.00
1970	$294.00
1971	$463.00 (estimated)[42]

Lockheed Missile & Space Company benefits and insurance payments were reported as $88,666,656 for 1970 on a gross payroll of $254,747,658 [43] or about 34%. To compare the Lockheed and General Electric figures is difficult from the figures made public, but it would appear that the Lockheed direct benefit dollars, such as vacation and holidays, should be added to the gross payroll and benefit expense combined with legally required payments. This ratio is $50,655,850 of payments for employees versus $292, 658,464 payments for employee time or 17.3%. Of greater concern perhaps

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[42] General Electric News, Pittsfield, Mass. Volume 57, No. 18, May 7, 1971

[43] The Lockheed Star, Volume 17, No. 9, May 7, 1971, Lockheed Missile & Space Company.

than the amount of benefits as a portion of wages is the increasing trend over a period. In some business segments the trend has been from 12% in 1967 to 18% in 1972 or about 1% per year.[44]

Industry also tries to motivate through plant newspapers, suggestion programs, cost effectiveness efforts, and similar promotional attempts. While each has a serious concern as its source, it often seems as though efforts are being exerted on a mass basis with things which inherently demand an individual technique. Company newspapers seem heavily oriented to personal items [45] and cost programs generally encourage by publicity of selected individuals as examples.

Summary

The large industrial plant bears many unique burdens. It underwrites the cost of refinements such as paved, lighted, protected parking lots, lounge facilities, and smoking areas which are not generally provided to the same degree by its smaller neighbors. These refinements in addition to their own cost carry peripheral tax and administrative costs along with them. The large plant is an attractive target for community issues, for union organizing, pattern bargaining tactics, and for employee frustrations generated by a progressively depersonalized organization.

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[44] Personal Experiences 1955 - 1971.

[45] Sample count of column space Lockheed Star seven issues from the period March 26, 1971 to July 30, 1971.

Sample count of column space General Electric News for Pittsfield issues from March 1971 to July 1971.

The small business may be inclined to minimize such costs, but it is hard to appreciate cost savings from attention not received. Large manufacturers must expect prime attention from all enforcement agencies for programs of public benefit such as taxes, health and safety, and equal opportunity. Normal efficiency of any control effort would dictate inspection of the largest segments first. Since the duration of any regulatory inspection is rarely limited,[46] the cost to a company of providing requested data is difficult to estimate.

The critical evaluation is; at what point does such visibility cause the big manufacturer to change production plans, and what direction will such changes take. Despite difficulties, industry has shown a much better record than any other segment of the economy in providing attractive worker benefits, in training "unemployable" labor segments into stable worker elements, and in producing hard goods at roughly, the same prices for twenty years while applying remarkably innovative techniques very rapidly.

It is suggested here that the success with the hard core unemployment problem is not basically different from the task of teaching non-english-speaking immigrants how to perform the less skilled tasks of a half century ago and that this has been one of the traditional success areas of American Industry since Eli Whitney. Further, the innovative techniques for improving production and productivity have followed a traditional path from the large manufacturer who can afford research to the smaller one who cannot.

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[46] William-Steiger Occupational Safety and Health Administration, Federal Register, May 29, 1971 Volume 36, No. 105.

It seems reasonable to suggest that the large plant should concentrate on the things it does best:

1. Research and development of technology, products, processes, and methods.
2. Assembly of components into finished products.
3. Training unskilled workers in assembly techniques and thus developing consumers and taxpayers as well.

Equally important is to reduce its disadvantaged attractiveness through judicious physical dispersion. When the level of technology is the same, the small shop can produce goods at less cost than the large one. Purchase of such goods will achieve both efficiency and dispersion. The tremendous flexibility of automated machines makes such an approach feasible. This feasibility will be explored in Chapter IV.

CHAPTER IV

FEASIBILITY

With respect to the job shop, the question of automation feasibility is whether it is capable of being done; whether it is practicable. Industrially, the measure is whether it can be done profitably or economically. The evidence already examined leaves little doubt that job shop automation is profitable for the large plant. It is not so easy to see similar advantages for the small business. Manufacturers considered representative, both large and small, were examined for recent trends. Three theoretical approaches were selected as references for forecast behavior. The sample is small, but seems to support the hypothesis of growth for the small automated job shop.

Several aspects of the general market affect the chances of small business success. The purchase practices of large manufacturers largely determine the size of the small business market. In addition, price, financing, and availability of the machine tools must be attractive before small business forms a significant demand segment of the machine tool builders' market. Finally, technology and maintainability must be in possession of the small firm so that it can use the new tools effectively. These aspects will be examined in turn.

Trends in Selected Large Corporations

Large corporations, selected for type of manufacture and annual sales volume, may be compared for their vendor practices and compared with capital intensive industry for examination of trends. Lockheed Aircraft Corporation, General Electric Company, and Chrysler

Corporation were selected for comparison and the steel industry is used because of its capital intensive characteristics and its dependence on heavy automated equipment.

Lockheed on a corporate basis during the first six months of 1971 awarded $95.8 million worth of contracts to small business (less than 500 employees and not dominant in the field) which represented one third of the $316.7 million total placed. The Lockheed Missiles and Space Company, A Group Division of Lockheed Aircraft Corporation, awarded $13.1 million in subcontracts and purchase orders to small businesses out of a total of $70.1 million for the period. That is 80% of LMSC's subcontracts and purchase orders went to small businesses in 48 states and the District of Columbia.[1] On sales of $2.54 billion in 1970, Lockheed purchased $316.7 million worth of vendor products or 12.5% of sales.

General Electric gave some comparative data for 1970. Over 50,000 suppliers provided goods and services at a cost of $4.3 billion which represents 49.4% of sales and was up from $2.1 billion or 45% of sales spent by the Company in 1961.[2] Chrysler Corporation shows 63.4% of sales went to suppliers in 1970 up from 57.9% in 1965 or $4.4 billion in 1970 compared to $3.1 billion in 1965.[3] Businesses oriented to defense contracts emphasize the support of small businesses in many

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[1] Small Business Gets Big Share, Lockheed MSC Star, August 27, 1971.

[2] Annual Report 1970, General Electric Company.

[3] Annual Report 1969, 1970, Chrysler Corporation.

geographic areas. Lockheeds' statement that "80% of LMSC's subcontracts and purchase orders went to small businesses" refers only to the number of vendors involved. In terms of dollars, just over 30% of vendor supplies were furnished by small businesses and only 18.7% of the defense oriented MSC vendor items. This appears low compared to about 50% for General Electric and about 60% for Chrysler. Table 7 shows comparisons for recent years. Three types of small business receive some market stimulus from the large enterprise: (1) the spin-offs of big company development effort either through a vendor relationship or through technical journal dissemination, (2) direct sale or royalty type of sponsorship, (3) the emergence of specialty centers.

Spin-offs. Some techniques are retained by the large corporation because of the logistics required for their support. For example, Lockheed has been able to carry out extremely complex stress analysis of huge tankers through the use of computer graphics, a technique where the computer constructs drawings based on the results of mathematical analyses.[4] Another example is chemical milling facilities, also at Lockheed, where caustic or acid is used to reduce weight by reducing cross sectional areas of structural missile or spacecraft parts to the minimum needed.[5] Both of these facilities require the maintenance of large resources of men, material, space, and handling capabilities. Such facilities can only be operated by a large enterprise.

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[4] Computer Graphics Work Helps in Tanker Study, Lockheed MSC Star, August 27, 1971.

[5] Chemical Milling is an Exciting Business at LMSC, Lockheed MSC Star, May 7, 1971.

COMPANY	ITEM	1970	1969	1968	1967	1966	1965
General Electric	Sales	8,727	8,448	8,382	7,741	7,177	6,214
	Supplies	4,074	4,126	4,062	3,694	3,702	3,063
	% to Sales	46.7	48.8	48.5	47.7	51.6	49.3
	Employee Compensation		3,511	3,325	3,082	2,930	2,526
	(1) Number of Employees		317,874	305,165	296,258	290,825	257,903
	% Profit to Sales		3.3	4.3	4.7	4.7	5.7
Chrysler	Sales	7,000	7,052	7,445	6,213	5,650	5,300
	Supplies	4,421	4,295				
	% to Sales	63.4	60.4	56.7	59.6	58.2	57.9
	Employee Compensation	1,784	1,813	1,802	1,467	1,339	1,223
	Number of Employees	228,332	234,941	231,089	215,907	183,121	166,773
	% Profit to Sales	(0.2)	1.4	4.1	3.3	3.4	4.5
Lockheed Aircraft Corporation	Sales	2,536	2,075	2,217	2,335	2,084	1,818
	Supplies	317	See NOTE 3				
	% to Sales		See Note 3				
	Employee Compensation	77.	78	70	68	NA	NA
	Number of Employees	92,000[2]	97,600	95,404	92,267	90,500	NA
	% Profit to Sales		(2.9)	2.0	2.3	2.8	3.0

TABLE 7

NOTES TO TABLE 7

1. General Electric Employees and Employee Compensation is for domestic employees only.
2. Lockheed employment is estimated based on a supplement to the annual report issued in September 1971. The report for 1970 failed to get auditors approval until Congress enacted legislative relief for the company. Lockheeds' practice is to give employment figures in the narrative rather than in the summary statements. Also the indecision over the L 1011 aircraft resulted in mass layoffs and rehiring. The figure given is considered accurate within 5 to 6 percent.
3. No data was available for years prior to 1970 on amounts paid to suppliers.
4. Sources of Table 7 data were the Annual Reports of the Companies listed. Choices are intended as typical examples of mass production, job shop, and sophisticated - exotic types of manufacture of roughly similar sales volume and customer diversity.

A phenomenon of the steel industry, however, is the recent upsurge of so-called Mini-mills. Although the first U.S. Mini-mill dates back to 1882, construction over the last 15 years has accelerated. A total of 33 were listed in 1967, 35 in 1969, and 42 in 1970 with several others being planned.[6] Capacities of the mini-mills range from 50,000 to 500,000 tons annually. Their strength lies in concentrating on widely used simple-to-make products (reinforcing rods) and locating conveniently close to their customers. A number are located near small towns in South Carolina, Alabama, Kentucky, and Tennessee. Their customers find them accommodating, responsive to last minute order modifications, and faster loading. Often there is a distinct transportation cost advantage. Mini-mills are dependent on scrap iron to feed their furnaces which makes their profitable operation dependent on the scrap iron price. With the amount of scrap represented by wrecked autos, there is relatively little reason to expect a significant scrap price variation.[7]

Another step toward manufacturing diversification and small shop capability is the one man Auto Forge being marketed by TMW division of North American Rockwell. This forge represents a diversification for a textile machine maker. The Auto Forge has somewhat similar advantages to the mini-mills. It is low priced at $80,000, can be operated by one man, reduces cost of small forgings from 18% to 40%, uses scrap metal, provides press forgings which are 10% stronger though slightly less ductile than conventional forgings, permits a higher lead content (up

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[6] 1970 Survey, Iron Age.

[7] The Mini-Mill: Steel on a Budget, Business Week, March 29, 1969
Thinking Small, The Wall Street Journal, October 26, 1970.

to 4.7%) while tolerances (0.005 in.) and speed (11 pressings per minute) are equal to those of good conventional forges. In addition, capital investment required to start such an operation from scratch can realistically be as low as $100,000.[8] The largest potential market is likely to be in carbon, low alloy, and stainless steels. Like the mini-mills, the one man forge makes it easy for anyone to get into the forging business which could encourage buyers of small forging to make their own. Present models limit maximum mold dimensions to 4 by 5 by 7 inches, practically to about 3 lbs. for brass and steel and 1 lb. for aluminum.

Steel, traditionally, has been one of the most capital-intensive of all industries where equipment costs are astronomical. Blast furnaces, steelmaking furnaces, plus rolling and finishing machinery require cash outlays in excess of $100 million. To produce a profit on such an investment requires volume production of over a million tons per year. The total present capacity of the mini-mills (six million tons) does not threaten big steel (195 million tons) but the shift to the basic oxygen furnace by big steel drove scrap prices down, providing cheap raw material for the small mill. It is doubtful at present that the mini-mills will broaden their product lines much. They represent a growing, successful small shop trend in a capital-intensive industry.

Sponsorship. Early in 1971, Lockheed authorized Anocut Engineering Company of Elk Grove Village, Illinois to ''design, to manufacture and to market machines to perform spark sintering''. Spark sintering is a process which produces parts of high density and pure

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[8] Forging Economies for Small Parts, Business Week, March 29, 1969.

composition. It is effective with metals ranging from tungsten and tungsten carbide through astroloy and inconel and on through light-weight metals including titanium, aluminum, and beryllium. The big advantage to the method is low tool costs which make small production runs economical.[9] U.S. Steel adopted a similar policy after developing continuous casting. Although the steel industry has been cautiously developing this process since 1962, U.S. Steel has been the most secretive in its efforts. The disclosure of the process by the company in April of 1969 represented a marked change of policy. They decided to sell the process to other steelmakers. To do so, a subsidiary called USS Engineers & Consultants, Inc. was formed and the process was demonstrated to Republic, Lukens, Steel Company of Canada, and Australia's Broken Hill Pty.[10] Advantages are increased speed, reduced cost, reduced waste (4% to 8% vs 14% to 20%) and a market predicted at 50% of U.S. capacity by 1972. Though the industry has developed several versions of the process, U.S. Steel appears to be the only one to have developed a company to go along with it.

Specialty centers. Separate from spin-offs and sponsorships are the specialty centers and small shops. Steel service centers which used to be brokers between steel mills and small steel users now represent 17.7% of the mills' shipments compared to 19.7% for the auto industry in 1967. Their function today is to buy large requirements from the mills, process the metal to specific customer needs, and provide rapid delivery. The service obviates the need for the small user either to

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[9] Metal Powder Molding Authorized, Lockheed MSC Star, February 12, 1971.

[10] A Ribbon of Steel Cuts Industry Costs, Business Week, April 19, 1969.

maintain a large inventory or purchase expensive processing machinery. Such centers have expanded rapidly in recent years. Williams & Company, Inc. of Pittsburgh, a seven-center chain has made 60% of its capital investment of the 20 year period 1947 to 1967 in the five year span of 1962-1967.[11] Ryerson claims that a customer can receive his shipment the day after his order is received and processed on nearly any Ryerson product. In addition to the small user market that first attracted the service centers to specialty work, a large percentage of the customers are the same companies that buy in bulk from mills - auto, farm equipment, construction equipment, and appliance companies.[12] The function in this case is a backstop. If, for example, a mill cannot get its steel to Fisher Body on time, a service center can fill the need at virtually a moments's notice.

Numerical Control Trends

The numerically controlled machine tool followed a pattern similar to the above examples.

Spin-offs. The trend on the part of large manufacturers to purchase universal machines or automatic machining centers and to set up special machining locations serving outside as well as internal customers carries special significance. The tough exotic metals now being used in aircraft manufacture require about six times the cutting capacity to maintain the same metal removal rate as aluminum alloy. In addition,

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[11] Steel Centers Show Their Mettle, Business Week, February 24, 1968.

[12] Ibid.

parts are substantially larger. The attendant requirements of greater accuracy and more physical rigidity of the machines have raised the price of large machines beyond the reach of many of the independent machine shops who serve as vendors to the large manufacturers. Big, complex, expensive machines purchased by large manufacturers are offered commercially to maintain machine loads similar to the targets shown in Table 4.

Sponsorship. Some large aircraft manufacturers developed plans to provide their sub contractors with the older or somewhat less sophisticated equipment. Grumman is carrying out plans to lease its first order of 104 machines to its subcontractors who will receive options to buy the equipment.[13] The combination of such lease with option arrangements plus the continuous assault on price for simpler machining operations such as two and three axis continuous path or contour operations creates distinct opportunities for smaller vendors.

Specialty centers. Small shops have always had trouble selling their talents to customers. Historically they have few employees, few tools, no salesmen and virtually no advertising budget. Manufacturing and Machining Services Corporation of Hillside, New Jersey was founded in 1960 by George D. Kaplan who then owned a 200 man shop. He developed M & M into a company of $50 million annual sales in less than six years. The formula was to bring together manufacturers who wanted parts cut, formed, or turned, and machine shops and job shops who had tools and the capacity to do the work on time. M & M provided a marketing service for

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[13] New Generation of Machine Tools Evolving, Aviation Week & Space Technology, April 15, 1968.

its 320 affiliated job shops, but it also provided careful technical evaluation for M & M customers based on Kaplan's own shop experience. For the job shop affiliate, M & M provided an identity, access to major contracts, advertising, warehousing, low cost transportation, cost analysis, uniform estimating procedures, and sophisticated management. The shops give M & M access to 39000 machine tools, 12% of which are numerically controlled. M & M takes 4% of the gross and turns the rest over to the Shops except where it has financed part of the job. Normal payment time by M & M to the shops is two weeks to 30 days whereas big manufacturers often force a small shop to wait months for its money. The primary strengths of M & M's approach are selection of only those shops which meet industry standards of quality, price, and delivery; commitment of a given number of machine hours per month usually representing unused shop capacity; and a loose affiliation based on sound mutual business interests. About 80% of the affiliated shops are working on M & M jobs at any given time. The orders to quotation ratio is 47.3% for M & M vs 10% to 15% for the individual shop. Prompt response and tight control of orders are chief reasons for repeat customers. The operating target for answering a request is 72 hours compared to two weeks for the average independent. In addition, the geographically scattered affiliates give M & M the option of using shops where any idle capacity exists including overseas. This is a big advantage in meeting delivery requirements if a particular job starts running late. Expediters are responsible to move materials to keep each job on schedule. To keep track of paperwork, the company used a data processing service bureau but acquired an IBM 1440 computer in 1966. The computer is used to estimate, accumulate manufacturing history, and keep track of production schedules, machine loading, and delivery performance.[14] In this case, use of the computer by M & M was directed to management of the business rather than to operation of the machines. The 4700 tape controlled machines available to M & M are totally within the control of the affiliated shops.

Technological developments. Over the last fifteen years the development of tape controlled machine tools has represented a significant manufacturing advance. In 1955 only four NC machines were displayed at the Machine Tool Show in Chicago. In 1960 there were 100 NC machines on display and though the excessive heat caused considerable trouble, the Milwaukeematic produced consistently throughout the show and really began the machining center revolution. Interestingly, though 1965 saw commercial design machines working consistently, one builder was refused permission to exhibit a computer which was to be used to prepare NC programs because computers were not machine tools. By 1970 one quarter of the machines exhibited included a computer in the control or were direct-connected to a computer, often in multiple machine combinations.[15] Many builders reduced their expenditures for the show because 1970 was a bad year. The omissions from the exhibit were the standard machines. They exhibited the new and the exotic. Customers also had reduced

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[14] Middleman on the Production Line, Business Week, June 11, 1966.

[15] Hanging on the Brink, American Machinist, October 5, 1970.

budgets for capital outlays in 1970. Even though 1970 funds were earmarked for standard tools, the customer representatives packed the demonstrations on computer control to inquire and to learn.[16]

Looking at the machine tool industry through the trade media provides a good appreciation of the general level of technology for an industry segment. Each firm uses appropriate existing technology for its output. Concurrently, each is working in some fashion to improve its level of technology for future output. A business must view its market from the base of its own technology because, industrially, level of technology is the first determining market barrier followed by price and delivery.

Theoretical considerations. Certain critical concepts[17] have been advanced with respect to what may be termed the central technology of the firm using the symbolism shown in Figure 4. The concepts of L, C, and A are considered stable elements because they provide a degree of continuity over time for a firm. The central technology C is capable of being separated into classes for a given business and also of developing, usually in discrete steps with respect to products furnished, as time progresses and as resources are committed. The result, if discrete states of central technology and related times are denoted by increasing subscripts (C_1, C_2, C_3,---C_n, and t_1, t_2, t_3, ---t_n), is a family of products over the years which satisfy increasingly complex functions.

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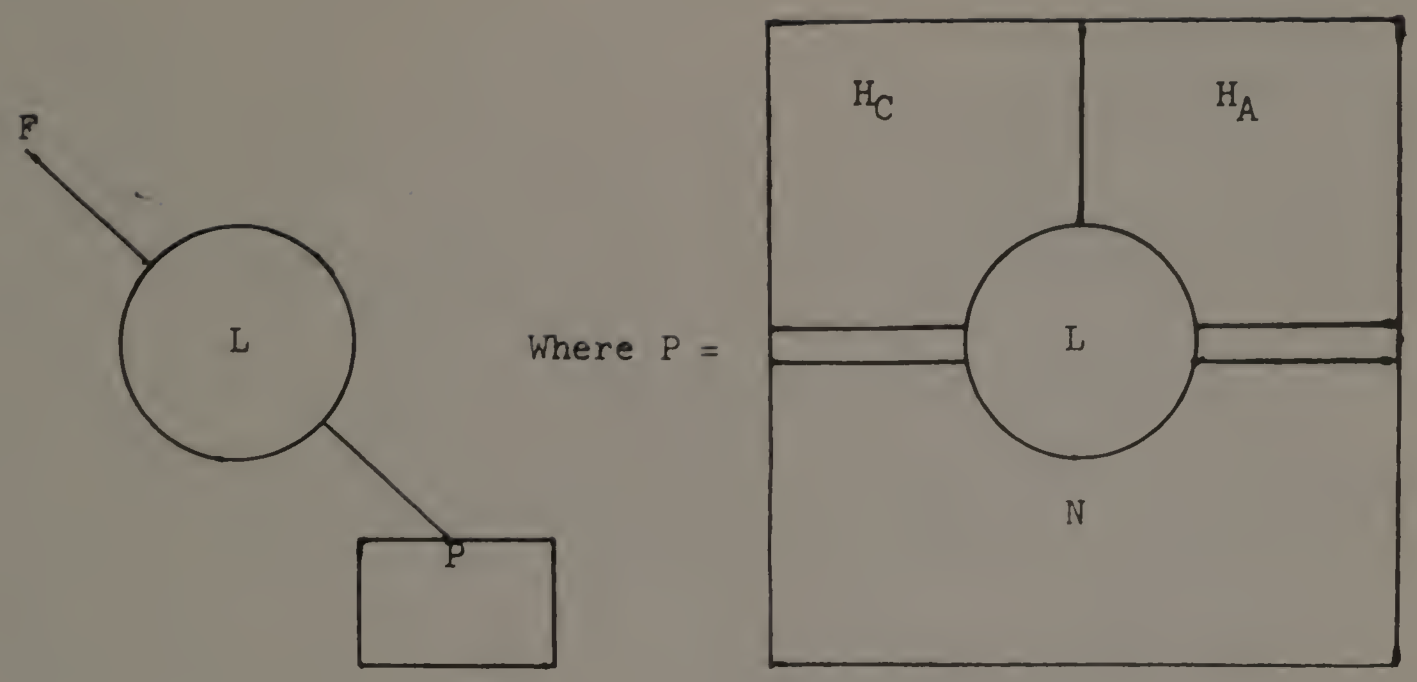
[16] Hanging on the Brink, American Machinist, October 5, 1970.

[17] Slate, H.B., A Set of Critical Concepts for the Ordnance Department 46 pp.



Where:

F. A specific function to be performed for a customer by a product

P A physical product for which the vendor is or expects to become a competent manufacturer

L A logic which makes possible fulfillment of an F by a P and relates the elements of P

C Central Technology of vendor

H_C Hardware element exemplifying C

A Ancillary Technology - an applied technology for major hardware elements but considered supplementary rather than central

H_A Hardware element exemplifying A

N Non-sequential hardware element of a P specifically tailored to each P, which together with H_C and H_A constitute P in a manner specified by L

Symbolism For Product And Product Function

FIGURE 4

Figure 5 represents product development with respect to time. The ordinate represents the maturity attribute of a central technology.

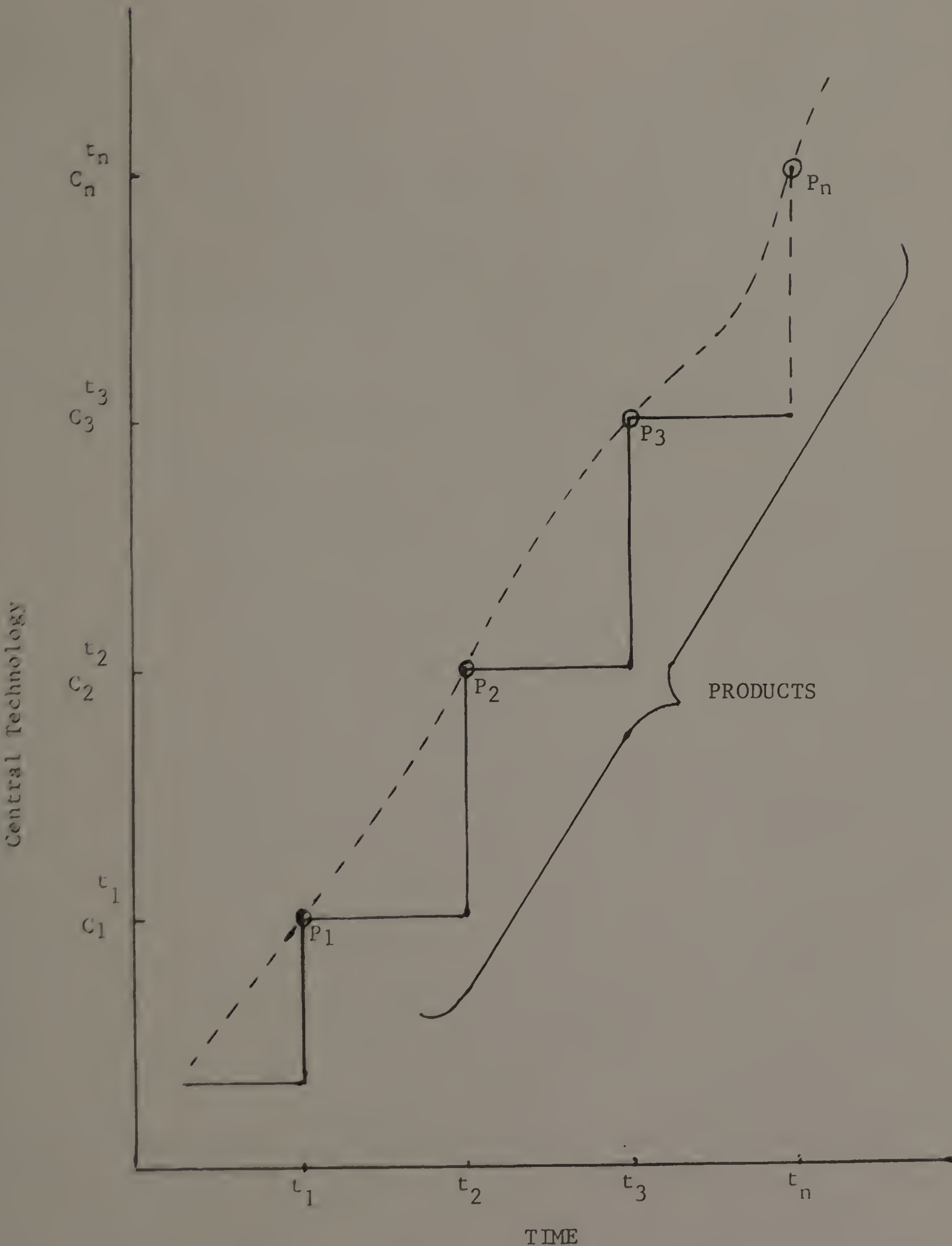
Competitive states can also be represented as a means of evaluating whether and on what grounds firm A should or must compete with firm B. If C is used to denote the central technology, and the state of advance of that central technology is denoted by t_1 for present and t_2 for future, then competitive states for vendors A and B may be compared as shown in Table 8.

	STATE OF C FOR VENDOR A	STATE OF C FOR VENDOR B	ALTERNATE NOTATION	WHO CAN DO
(1)	C^{ta1}	C^{tb1}	C^{ta1tb1}	Both
(2)	C^{ta1}	C^{tb2}	C^{ta1tb2}	Vendor A only
(3)	C^{ta2}	C^{tb1}	C^{ta2tb1}	Vendor B only
(4)	C^{ta2}	C^{tb2}	C^{ta2tb2}	NEITHER

Comparative Competitive States for Vendors
Table 8

Condition (1) says that if both vendors possess the needed technology and it is all that is needed to satisfy F, then price will ordinarily be the dominant competitive factor. The other extreme is condition (4) where neither vendor possesses the technology at present to satisfy F. If they are able to compete (other vendors do not have the technology either) it will have to be on the basis of past demonstrated performance and on present technological approach. The award of the U.S. Supersonic Transport development to Boeing Airplane Company is an example of successful competition under condition (4).

It then follows that any existing state of technology must be exploited to avoid wasting it and the firm's central technology must be



Discrete States of Central Technology
Represented by Products with Respect to Time.

FIGURE 5

advanced constantly in order to avoid loss of competitive position. For the small shop, advancement of the central technology must mean acquiring some state C^{t2} from a large firm for whom it is already in a C^{t1} category. Except in rare instances, the small shop in acquiring successive states of technology is in reality merely increasing the number of firms who share that state of technology and therefore must expect to compete and succeed on the basis of price and delivery. The growth of the mini-mills, auto-forges, and specialty steel shops suggests it can be done. Their growth also demonstrates that when a state of technology is shared equally by a large shop and a small one, the small shop can compete successfully on price basis. Whether the shop is independent or a member of an M & M type affiliation, the advantages of NC machines are much the same. First, tape is simply another aid in the basic problem of presenting the tool properly to the work. As automatic hard tooling took over large lot runs, the demand on special machines shifted to smaller lots. In turn this resulted in use of quick set tooling which lowered the lot size a machine could handle economically. This, in its turn, reduced the required machinist skills. Second, tape reduces cutter setting time but does not affect time required to change tool holders. These were redesigned to provide essentially universal tool holders which remain in place for most machining environments. Third, the emphasis of responsibility tends to shift from man to machine. Fourth, the ability of these machines to remove metal combined with an efficiently programmed path enables them to outproduce an automatic.[18]

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[18] Fingerhut, H.J., Automation of Small Lots, Tooling and Production, September 1968.

In terms of production rather than in terms of the tools, advantages are; improved accuracy, higher production rate, lower tooling costs, shorter lead time, reduced inventory, reduced inspection time, and increased repeatability.[19]

Maintenance and input considerations. The machine elements represent very little in terms of advancing technology for the user. By the same token, there is very little difference in machine technological expertise between the small shop employee and his large plant counterpart. In operator controlled machines, by reference to Figure 5 and Table 8 it is reasonable to conclude that there is no difference in output quality. However, when tape-inputted electronic controls are applied to these machine elements, a marked increase in technological level has occurred. Not only has the precision of the machine elements been increased, but also the required expertise has changed from mechanical-hydraulic to electronic. The large plant can make such a shift quickly and, in some cases, lead the way in development or application. This posture is possible through the combined expertise available to the large firm. The small shop must rely on individually developed interest, knowledge, and technique gleaned from relatively random sources.

The obvious deterrent to small shop automation has been the ''computer assist'' rather than the ''machine tool'' portion of the combination. Major initial obstacles were such things as:

1. Tapes, tape storage, computer language variation.

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[19] Martin, Warren O., Small Lot N/C Pays Off, Tooling and Production, September 1968.

2. Machine model differences from year to year in that the same inputs resulted in different commands.
3. Differences in critical machine axis dimensions and miscellaneous functions plus three axis versus two axis capability adversely affect tape interchangeability.
4. Variations in available ‘‘canned programs’’ and availability of such programs.
5. Adequate instruction in timing, programming, and tool handling techniques for fast acquisition of NC advantages.
6. Development and proper use of test tapes in addition to operating tapes.[20]

Solution to these types of difficulties was achieved through industry association leadership in establishing uniform standards. The standards group of the Electronics Industries Association initially attempted to utilize the MAGIC 2 coding to compensate for differences in the feed increments and ranges of different machines. This eventually had to be expanded to include other methods applicable to a wider range of manufacturers' equipment. While the E.I.A. standards did provide uniform definition for such elements as axis order and description, rotation about an axis, sequence of address and standard functions, and a binary number system; the standardization of feed increments and ranges alone would cost $6000 to $8000 for each machine and still complete interchangeability would not be assured.[21] Economically, it was much

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[20] Knauss, W.P., Jr., Numerical Control Lecture Series, pp. 12-25.

[21] Ibid.

better to program directly to Inches Per Minute with computerized programming, utilizing the post processor to compensate for the differences in the feed range.

Now, computer manufacturers offer program libraries and programming assistance to their customers. In addition to Honeywell, IBM, and General Electric, many smaller companies have successfully entered the field as typical ''downstream'' firms supporting the large capital goods computer hardware industry.[22] Such firms as Computer Sciences Corporation, Computer Applications, Inc., Computer Usage Company, Computing and Software, Inc., and Planning Research Corporation are among those sharing the $2.5 billion to $3.0 billion software market that now exists in addition to the $5 billion to $6 billion hardware market.[23]

Economic considerations for the firm. The main concern of the firm is total operating costs of a proposed method versus the existing method. For comparison purposes, conventional machines may be classed as Large machines and Small machines while the NC's are considered as a group. Large machines are horizontal boring mills such as Lucas 54B120 or Giddings and Lewis H5 or a jig borer such as Fosdick 54P. Small machines are turret drills such as Burgmaster 3BHT-B or 3BHT-L. More broadly, Large machines may be classed as boring mills with table and head travel of sixty inches each or more, saddle or cross rail travel of forty inches or more spindle travel of twenty-four inches or more, and table work surfaces of approximately 3000 square inches and over. Jig

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[22] Software Gets a Hardsell Approach, Business Week, October 21, 1967.

[23] The Men From the Boys, Forbes, October 15, 1967.

borers in the Large machine category have table travel of fifty inches or greater, head travel of twenty-one inches or more, saddle travel of at least eighteen inches, and spindle extension of eight inches and up. Work surface area is at least 1200 square inches.

Small machines such as turret drills and single spindle machines have table travels generally under forty inches although some might be as great as sixty inches. Saddle travel is thirty inches or less while spindle or turret travel is in the range of eight to twenty inches. Knee or head travel is also in the eight to twenty inch range.

Several separate cost centers may be delineated for more accurate comparison. Ten relatively common ones are:

1. Planning and Programming - Responsible for specifying machining sequence, where operations are to be performed, and time requirement estimates. For NC, selects machine and does manual programming including tape preparation.
2. Tool Engineering - Designs and provides fixtures, cutting tools, preset tools. For NC maintains preset tooling and provides tool length data to programming group. Cost of computerized programming and training for manual programming is here also.
3. Plant Engineering - Foundation Drawings, air, hydraulic, and electric power supplies and similar machine needs.

4. Quality Control - Process control, vendor appraisal, metrology, incoming and in-process inspection.
5. Maintenance - Labor and material cost of keeping the machines operating efficiently including any special technicians required for NC.
6. Production Control - Expediters, clerks, dispatchers, storekeepers and similar personnel.
7. Equipment Development - Preparation of specifications, selection of equipment, performance of acceptance tests, start-up.
8. Facilities Engineering - Study of plant layout, material flow, future needs, cost justification for machine funds appropriation.
9. Supervision - Direct factory supervision
10. Direct Labor - Machine operators

Cost of factory and office space plus miscellaneous expenses must be added to the direct and indirect costs accumulated in the itemized cost centers. To arrive at an operating cost per operator-hour or machine-hour rate the total dollar cost is divided by the man-hours necessary to run the machines. On an annual basis this is 40 hours per week x 48 weeks x the number of direct men in the area (Large, Small, or NC). Table 9 gives the breakdown in terms of the machine hour rate converted to a standard dollar. The results in this case proved to be \$11.00 per hour for the Small Machine Shop, \$9.20 per hour for the Large Machine

TABLE 9

COST BREAKDOWN FOR CONVENTIONAL AND NC SHOPS

COST CENTER	SMALL MACHINE SHOP	LARGE MACHINE SHOP	N/C
Planning & Programming	$ .031	$ .027	$ .137
Tool Engineering	.168	.127	.112
Plant Engineering	.001	.001	.031
Quality Control	.100	.063	.050
Maintenance	.060	.040	.151
Production Control	.124	.149	.074
Equipment Development	.018	.007	.065
Facilities Engineering	.003	.004	.008
Supervision	.015	.027	.007
Direct Labor	.295	.354	.215
Miscellaneous	.185	.201	.150
	$ 1.00	$1.00	$1.00

Source: American Machinist
June 8, 1964

Note: The 'standard dolar' for each operation is a percent figure. All costs assigned to the respective areas are divided by the man-hours applied to the machines to arrive at the figures given on p. 75. If this total amount of cost were used as 100% or $1.00 and the costs proportioned, the results would be as shown above.

Shop, and $17.10 for the Numerical Control Shop. The rate for the NC's included depreciation of universal and modular tooling.[24] The savings are realized in the comparative machine times needed and the repeatability or reduction in scrap and rework. For the illustrative cost in Table 9, the operations were largely drilling, tapping, and boring where the average ratio of conventional machine time to NC time was 3 to 1. In particular cases the ratio was as high as 4.8 to 1. The ratio from five representative jobs in Chapter II page 25 from a general purpose machine shop was 2.8 to 1 which compares favorably with the 3 to 1 given above. Our representative comparison for actual operating cost would then be:

Small Machine Shop	Large Machine Shop	N.C.
3 x 11.00 = $33.00	3 x 9.20 = $27.60	$17.10

on a per hour basis. For the study represented by Table 9, scrap and rework savings were $11,000 per year while a single machine from the Chapter II example provided scrap savings of $1500 annually over conventional methods. This data supports the position that for job shop quantities, NC machines are cheaper to operate than conventional machines. The amount of savings will depend on the number of machines and the kind of work usually performed plus the fact that indirect costs will be cut as the NC shop expands and allows them to be spread over more machines.

It was evident at the Machine Tool Shows in Chicago during October 1970 and at Philadelphia in May 1971 that a complete range of hardware and software is now being actively offered at attractive prices

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[24] Figuring Where N/C Pays Off - A to Z Comparison of N/C and Conventional Methods, American Machinist, June 8, 1964

with flexible options.[25] The additional advantages to be gained are the use of time-sharing systems such as Compact II which has already resulted in a 30% efficiency increase in NC machines already in use and an 85% improvement over manual programming time.[26]

Two corollary advantages are the use of the computer for production control, and the use of NC techniques to improve performance on standard machines. The degree of computer application will increase with number of employees, number of different parts manufactured, and number of active manufacturing orders at any given time. Such expanded computer application can:

1. Reduce in-process inventory
2. Reduce manufacturing lead time
3. Provide accurate picture of machine utilization
4. Provide a means for prompt reaction to change; therefore more effective management of production facilities.

Use of the computer for production control can be an effective reporting tool for customer interface. The second item, programming non-NC tools, can increase productivity and reduce time required for operator calculations. The technique involves the use of digital readout monitors to sense standard machine motions and requires the preparation of detailed operation sheets from basic machine component drawings. These sheets specify step-by-step position readouts for the machine operator in a way similar to the preliminary programming steps used for numerical control

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[25] <u>'71 Tool Show Report</u> - American Machinist, May 17, 1971

[26] <u>Tapes by Time-sharing Save Time</u> - American Machinist, October 18, 1971

machining operations. Since this method supplies picture charts and easy-to-follow instructions, the operator does not become involved in preliminary calculations and settings while the machine remains idle. On large machines production rates can be doubled and direct labor per part cut in half. Reduction of in-process inventory is also achieved. These savings are achieved on non-NC machines at half the cost of an NC machine tool. For small non-NC machines there is no advantage in using this technique. Generally, the operator works with a simple blueprint and any attempt to prepare programming sheets would be an effort in duplication. Also, downtime to chip time is not nearly as critical on small machines as on large ones.[27] These conclusions with respect to large and small machines on the non-NC variety are generally supported by Table 9.

Economic and financial considerations for industry. The machine tool industry was concerned about the future after the boom years of capital spending growth in the mid-1960's. At a meeting of the National Machine Tool Builders Association in May 1968, Clopper Almon, Jr. forecast, from the University of Maryland's input-output model of the U.S. economy, that the adjustments faced by the machine tool industry were less severe than might appear mainly because of technological changes. Technological change for machine tool builders has taken the form mainly of numerically controlled equipment. Almon's data (see Table 10) indicate that five of six categories of machine tools studied will benefit from technological trends now at work. It seems significant that the two categories showing the largest forecast growth rates with technological change are

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[27] Programming Non-NC Machine Tools, American Machinist, May 17, 1971

AN INPUT-OUTPUT FORECAST OF MACHINE TOOL DEMAND 1966 - 1973

TYPE OF MACHINE TOOL	ANNUAL GROWTH RATE	
	With No Technological Change	With Projected Technological Change
Boring Machines	1.6%	- 0.2%
Drilling Machines	2.9	8.2
Gear Machines	1.8	3.6
Grinding Machines	2.8	3.6
Lathes	3.1	5.6
Milling Machines	2.2	3.4

Data: University of Maryland

TABLE 10

drilling machines and lathes which are fundamental components of general machining output. From the price emphasis and options available at the Machine Tool Shows of 1970 and 1971, it appears that the NMTBA took Almon's forecast seriously. R. K. LeBlond Machine Tool Company in 1969 introduced a chucking lathe with an automatic tool changer that works without interrupting machining. The tape controlled machine can select any of 16 tools and sells for $140,000. Kearney and Trecker the same year offered a machine that mills, drills, taps, bores, reams, and turns. It has a 20-tool magazine and a work piece changer that loads or unloads a second chuck without interrupting machining. The price for this unit is $225,000.[28]

The biggest single boost to the small shop is the willingness of financial institutions to underwrite large capital outlays by very small enterprises. A salesman was pleasantly surprised when he sold an NC punch unit for $250,000 to a small machine shop having no more than a dozen employees and he found that the bank agreed to the financing.[29] Another financial aid is the recent liberalization of rules on depreciation by the Treasury. The present trend appears to recognize the need to update equipment more rapidly to counter obsolescence, increase productivity, and keep pace with very rapid technological advance. The depreciation allowance revision of January 1971 which included the key features of (a) an optional asset depreciation range of plus or minus 20% of the standard (b) a choice of first year conventions allowing more

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[28] Two Tool Makers Grind Down Efficiency Gap, Business Week, March 15, 1969

[29] Cheaper Automatic Machining, Business Week, April 10, 1965

generous deductions soon after installation and (c) abolition of the reserve ratio test, was given a very cool reception by economists and others as an item of major effect in spurring capital spending. The short term effect is expected to be more in the nature of releasing orders which were held in abeyance for several months after having been quoted. A change in the general business climate has a far greater impact on capital spending than a change in depreciation rules. Here, however, the concern is with small shops whose investments are marginal in terms of the total market or total economy, and the effect of rules change on depreciation could swing the balance toward placing an NC machine order. Third, the expanding scope and influence of the Small Business Administration which, though currently emphasizing minority led businesses, has historically assisted tiny companies in industries where small concerns are prevalent. A recent new policy proposal would allow SBA to aid any supplier who held less than 5% of the total market. This would allow American Motors to qualify as a small business among others, but the thrust is a clear increase in scope over the previous charter.

The machine tool industry has made more tools available with wider options at attractive prices. Between the banks and the government money managers, affording the price has become easier. In Chapter III it was suggested that many segments of overhead expense were less for small shops than for large plants. It was demonstrated earlier in this chapter that for a given level of central technology, one shop can produce output equal in quality to another. The small shop proprietor must then determine how much he should spend to acquire new levels of technology or how far he should attempt to penetrate an attractive market in a given period. Mr. F.S. Hammer[30] developed a portfolio theory for accumulating stocks of monetary and physical capital which suggests an approach for the small shop.

<u>Hammer wealth model for the firm</u>. Traditional theory[31] is concerned with flows in order to answer the question: What is the optimum rate of output, given demand, cost, and market structure? Mr. Hammer's approach allows a new perspective to be brought to the theory of the firm. Both theories accept maximization of profit as the primary desired goal. But where traditional theory formulates the profit function as the difference between revenues and costs, the new model views profits as the difference between yields on stocks of assets and the rate of payments emanating from stocks of liabilities. Also, the firms's wealth (net worth) replaces the production function as the constraint with respect to which the profits function is maximized.

If the firm is considered to have a stock of assets, a, and a stock of liabilities, l, then the portfolio is measured in "standard units" which may be thought of as constant dollars. The firm deals in three markets; the asset market, capital market, and the product market. For present purposes, long run considerations are pertinent; therefore, decisions will be considered made in a static framework. Prices for assets and liabilities, respectively, are denoted by Pa and Pl. Assuming yeilds as constant streams, true yield (p_a and p_l) and nominal yields (r_a and r_l) are related to prices through the following equations:

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[30]Hammer, Frederick S., <u>The Demand for Physical Capital: Application of a Wealth Model</u>, 137pp.

[31]Samuelson, P.A., <u>Foundations of Economic Analysis</u>, Chapter 4.

$$(1) \qquad P_a = \frac{r_a}{p_a}$$

$$(2) \qquad P_1 = \frac{r_1}{p_1}$$

and wealth of the firm, W, is the difference of market value of assets and liabilities:

$$(3) \qquad W = P_a a - P_1 1$$

Similarly, P_d can be designated as the unit price per product, and quantity of production as Q so that

$$(4) \qquad P_d = P_d \ (Q)$$

Equation (4) is the demand curve in the product market. For any quantity of output Q produced and sold in the product market there is some stock of assets, a, which can be chosen so that:

$$(5) \qquad Q = Q \ (a)$$

Continuing to the remaining elements of the firm's product output equation:

C_q denotes total cost per period incurred in producing the firm's total output and composed of C_c and C.

C_c denotes total costs incurred in producing output for the period exclusive of interest payments on outstanding liabilities.

C denotes debt costs as payments on the firm's liabilities.

Then:

$$(6) \qquad C_c = C_c \ (Q)$$

$$(7) \qquad C = r_1 1$$

$$(8) \qquad C_q = C_c (Q) + C$$

Using consistent notation for revenues:

R_q denotes total gross revenues from selling output in the product market

(9) $R_q = P_d\ (Q)\ Q$

and R = gross revenues minus costs of production

(10) $R = R_q - C_c = r_a a$

Profit, π, is the net of revenues and debt plus production costs or from (10) and (7)

(11) $\pi = R - C = r_a a - r_1 l$

Since maximization of profit is accepted as the primary goal of the firm by both the flow theory and Hammer's portfolio theory, maximization conditions require inspection. The marginal rate of profit is a relationship between profit and wealth of the firm[32] and, at equilibrium, the firm will adjust its asset-liability portfolio so that marginal net revenues and marginal debt costs are proportional to the price of assets and liabilities respectively. The common factor of proportionality is the marginal return on wealth.[33]

A graphic approach is provided in Figure 6. For the graph, budget lines and iso-profit curves will be used. Thus, once a portfolio is determined, nominal yields (r_a, r_1) are fixed for any point on an iso-profit curve and movements along the curve are considered as reflecting changes in true yields or prices. Prices are no longer considered constant.

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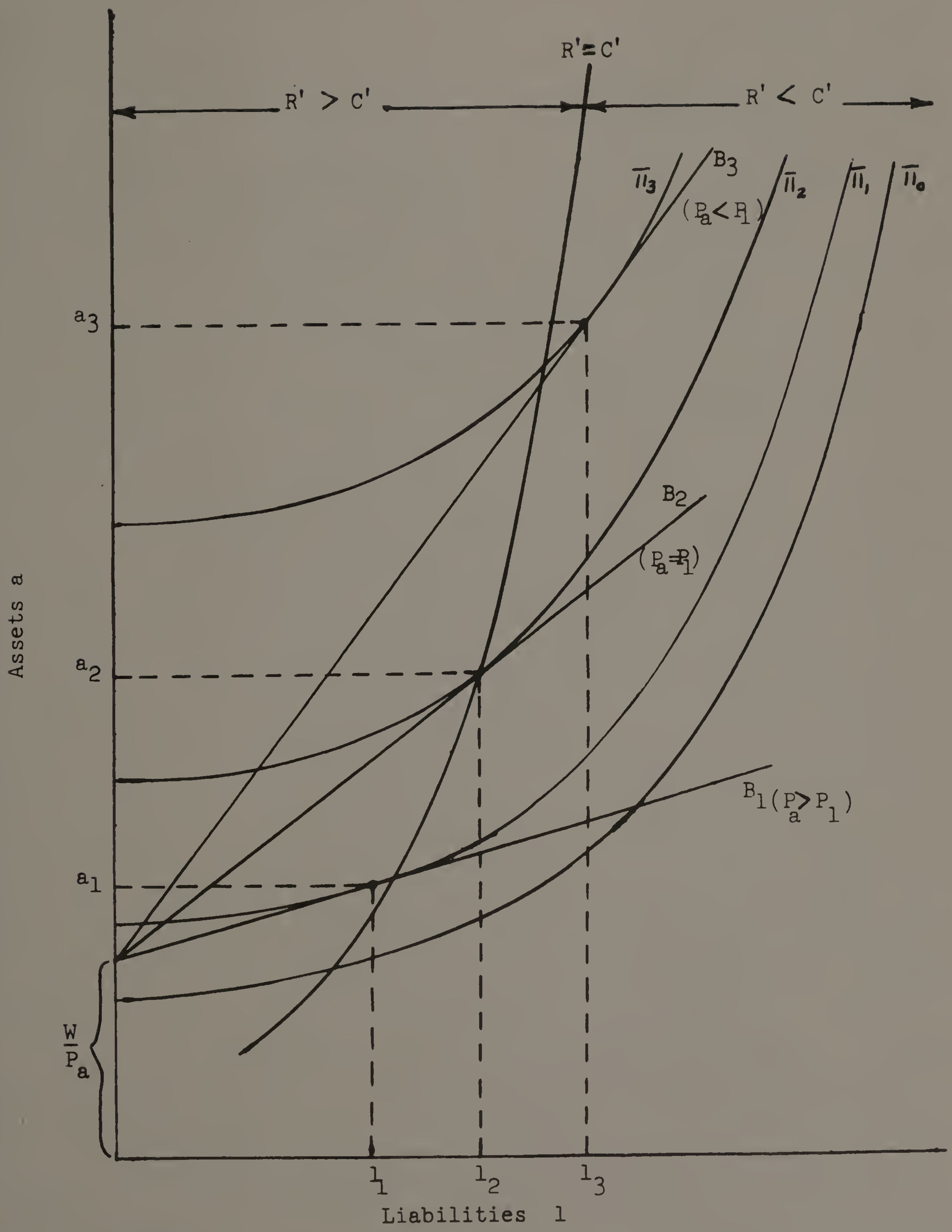
[32]Hammer, Frederick S., The Demand for Physical Capital: Application of a Wealth Model pp. 35-36

[33]Mosak, J.L., General-Equilibrium Theory in International Trade, Chapter 1.



Optimum Portfolio for Given Profit Curve

Figure 6

The shape of the iso-profit curves in Figure 6 ($\pi_0 < \pi_1 < \pi_2$----) are derived from the relationship between marginal net revenues and marginal debt costs (R',C') and that between total net revenues (R), assets (a), debt costs (C), and liabilities (l). R' and C' are first derivatives of equations (10) and (7), respectively:

$$(12) \quad R' = \frac{dR}{da} = r_a + a\frac{dr_a}{da} = r_a + ar_a'$$

$$(13) \quad C' = \frac{dC}{dl} = r_l + l\frac{dr_l}{dl} = r_l + lr_l'$$

The slope of an iso-profit curve in the a, l plane of Figure 6 may be found by finding $\frac{da}{dl}$ when $d\pi = 0$. Differentiating (11) gives

$$(14) \quad d\pi = (r_a + ar_a')da - (r_l + lr_l')dl$$

When $d\pi = 0$

$$(15) \quad \frac{da}{dl} = \frac{(rl + lr_l')}{(r_a + ar_a')}$$

Substituting from (12) and (13)

$$(16) \quad \frac{da}{dl} = \frac{C'}{R'}$$

The slope $\frac{da}{dl}$ is < 1 if R'>C' (17)

= 1 if R' = C' (18)

> 1 if R' < C' (19)

To keep profits constant any shift in portfolios requires changes of equal amounts and direction for costs and revenues. Therefore from (17) more than one unit of l must be added for every unit of a added for profits to remain constant. In (18) a one for one relationship exists while in (19) it can be seen that for every unit l, more than one unit of assets must be added for profits to remain constant.

It was stated earlier that the net worth (wealth) of the firm would be used as the constraint against which profits are maximized. To introduce wealth to Figure 6, equation (3) is rewritten in terms of a.

$$(20)\quad a = \frac{W}{P_a} + \frac{P_l}{P_a} l$$

The first term becomes the a intercept while the second establishes the slope of the budget (wealth) line. The slope P_l/P_a is the ratio between the price of liabilities and assets. Also, differentiating equation (3) gives

$$(21)\quad dW = Pada - P_l dl$$

If W is considered constant for the optimum conditions shown, then dW = 0 and

$$(22)\quad \frac{da}{dl} = \frac{Pl}{Pa}$$

Substituting from (16)

$$(23)\quad \frac{C'}{R'} = \frac{P_l}{P_a} \quad \text{or} \quad R' = C' \frac{P_a}{P_l}$$

Now Figure 6 may be examined in terms of price, marginal revenues and costs. If the three budget cases are examined, it may be seen that:

B_1 where $P_a/P_l > 1$, the condition may only satisfy 9230 if $R_l' > C'$ and the optimum point on π_1, is a_1, l_1.

B_2 where $P_a/P_l = 1$, then (23) is satisfied only if $R' = C'$. The optimum point is a_2, l_2 on curve π_2.

B_3 where $P_a/P_l < 1$, then (23) is satisfied when $R' < C'$ and the optimum point is a_3, l_3 on curve π_3.

Profits have increased as the firm has grown ($\pi_3 > \pi_2 > \pi_1$, $a_3 > a_2 > a_1$) and for a given wealth, the optimal size of the firm[34] increases as the

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[34] Collins, N.R., Preston, L.E., The Size Structure of the Largest Industrial Firms, 1909-1958, American Economic Review, 1961 pp 986-1003.

price of liability units increases with respect to the price of asset units. That is, with increase in the size of the firm, the price at which it can take on an extra unit of liability increases. But for a given increase in real liabilities, the firm can acquire more real assets.

For a given ratio P_1/P_a the optimal firm size is finite because beyond some point, debt costs increase faster than net revenues. The assumption here is that interest costs tend to rise with an increasing debt-equity ratio[35].

Application of Hammer Wealth Model. If two situations are examined with respect to the small shop, some general conclusions may perhaps be drawn as to the present market attractiveness. First, a perfect product market will be assumed. That is all products made can be sold or that there is a constant increase between stocks of assets and liabilities. If the firm has been operating on the π_1 B_1 curve of Figure 6 ($P_a > P_1$), any downward change in the asset market will tend to cause the firm to approach $P_a = P_1$ or B_2 π_2 condition. Such changes in the capital market are occurring when prices of capital equipment decline. Acquisition of NC machines gives about a 3:1 cost advantage which further improves the rate of return on total stocks of assets and contributes to a move toward receiving more than one unit of revenue for each unit of cost ($R' < C'$). Additionally, the availability of easier financing reduces the price of liabilities see (2) and contributes to growth of the firm and movement from π_1 curve toward π_2 and π_3.

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[35] Modigliani, F., Miller, M., The Cost of Capital Corporation Finance and Theory of Investment, American Economic Review, 1958 pp 261-297.

Second, the competitive market must be viewed from two aspects: (a) What competitive chance has the small shop against the large one since the assumptions above favor machine acquisition by anyone, and (b) What is the chance of the small shop competing against other small shops?

Competitive Market View. The competitive market must be viewed against Slate's concepts: to fail to advance the state of a central technology or to fail to exploit an existing technology is to lose competitive position. In terms of (a) above, the problem is evaluating the competitive chance. Again Slate's concepts apply: where technologies are equal, competition is on price. The small shop cannot compete on large subsystems because of product size, facilities, perhaps technology, and net worth (see Figure 6). It can successfully compete on components where the aforementioned items disappear as constraints.

A different aspect of the situation is the policy of large firms in awarding orders to small business. On government contracts this practice is encouraged. Table 11 shows the percentage of small business awards in recent years for the nation, for the General Electric Company, and for General Electric's Ordnance Systems Department in Pittsfield, Mass.

	NATIONAL AVERAGE	GENERAL ELECTRIC COMPANY	GENERAL ELECTRIC ORDNANCE SYSTEMS
1969	40.6%	44%	37.5%
1970	36.7	37	39.7
1971	35.0 (Est)	35.8	41.1

COMPARISON OF GENERAL ELECTRIC SMALL BUSINESS AWARDS AGAINST NATIONAL AVERAGE

TABLE 11

Analysis of the figures for General Electric Ordnance Systems, however, shows that of the amount of awards available to small business (after excluding the mandatory large business awards) between 87% and 94% were placed with small businesses and those that were lost by small business were lost on the basis of being technologically non-competitive or choosing not to bid.[36] The figures are considered indicative because the Ordnance Department is included in aerospace statistics and was cited by the Department of Defense in 1971 for its past performance in placing orders with small business vendors. The available market is probably larger because directed purchases from large firms excluded the small plants from some competitively available work. The percentages are considered conservative because of the mentioned restriction and the fact that they are taken from a business segment cited for its efforts. The small shops could expect to capture a 6% to 13% greater market by exploiting currently available technology.

Though direct comparison is difficult, small shops cannot match large plant labor rates, but they have little trouble getting labor.[37] Small shops are often non-union and operate on the basis of work to be done rather than on division of labor. That is, in the small shop, the customer may discuss his job with the machine operator who at that moment is performing a marketing function, perhaps followed by an applied labor operation, and then a material move or a shipping effort. These efficiencies are no longer obtainable in the large shop.

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[36] Reports on Ordnance Systems Small Business Program from Ordnance Systems Dept. General Electric Company to Naval Plant Representative, Strategic Systems Project, dated Jan. 28, 1971, Oct. 26, 1971, Nov. 9, 1971, Jan. 17, 1972.

[37] Personal interviews - see Appendix D

Today, obtaining labor for this type environment depends on worker attitude. For the successful worker (the one who holds a job) skills in the large and small shop may be assumed equal. Interviews were conducted with a number of men employed in both large and small shops during the period March 1969 to June 1970. Opinion centered on preference for individual identity, skill, and pride of workmanship plus feeling of personal responsibility, independence, friendship, and teamwork. The men had successfully applied for employment with General Electric and E. D. Jones Division of Beloit Corp., but had elected either to decline offers in preference to a small local establishment or to resign after short employment. They have good reputations in the community both as workmen and as citizens, are active in church and youth work in addition to holding a full time job and working at sidelines. They felt they could ''not stand'' the group methods of the large shop, did not like the union restrictions on their work accomplishment, though they are not anti-union, and felt it was worth a lower hourly rate to have a job they liked which seemed to interpret to a personal acquaintance with all employees of the firm. In discussing benefits, the consensus was that Blue Cross group insurance matched the illness provisions of large company plans and that such provision was adequate. Pensions and similar items they could arrange independently and felt it was not a ''price to pay'' but rather a chosen option. One man had worked in a small textile mill where the Christmas bonus had pretty well closed the gap of pay differential. Another had worked for a milk company as a route man and felt that Christmas gifts from customers offset any pay differential. Those holding jobs with large employers indicated sympathy for such opinions and often a desire to change to that type of job, but seldom the initiative to make the actual break unless forced to by layoff or other circumstances.[38]

Another measure is that of benefits as a burden on direct labor. Earlier, comparisons were made between Lockheed and General Electric showing them to be within about 2% in benefits payments. Putting these on the same base as nearly as possible indicates a range of 32% to 35% benefits.[39] The assumption here is that any pay for personal, illness, death in family, jury or military duty, vacation, and holidays plus insurance, medical care, and pension is considered a benefit. Payroll is that payment only for time on the job. The small shop estimate obtained on a similar basis was 28% to 30%.

An attempt was made to compare representative labor and benefit items among fifteen companies doing business in Berkshire County, Massachusetts. Average paid rates for similar job classifications were used while rate span was ignored because actual present costs were considered pertinent to this study. Firms are grouped into large (having more than 200 direct employees) and small (having less than 200 direct employees). For specific classifications, paper, textile, electrical, and machine shops were included although not every firm had employees in each chosen category. Non-industrial businesses such as banks were deleted from direct comparison although they could not be extracted from figures of class averages. Table 12 gives the results. Note that only in items 6 and 7, Assemblers, do the small plants pay more than large plants for

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[38]Personal Interviews see Appendix D.

[39]Chapter III page 50

Classification		Average Paid Rate		
	Hourly Jobs	Large Plant	Small Plant	All
1.	Tool and Die Maker A	$4.815/hr.	$4.720/hr.	$4.78/hr.
2.	Tool and Die Maker B	4.318/hr.	3.802/hr.	4.11/hr.
3.	Welder A	4.437/hr.	4.420/hr.	4.43/hr.
4.	Light Machine Operator	3.405/hr.	3.270/hr.	3.36/hr.
5.	Horizontal Boring Mill Operator	4.626/hr.	3.920/hr.	4.39/hr.
6.	Assembler A	4.030/hr.	4.640/hr.	4.23/hr.
7.	Assembler B	3.047/hr.	4.020/hr.	3.37/hr.
8.	Stockkeeper A	3.432/hr	3.310/hr.	3.09/hr.
9.	Maintenance Technician	4.057/hr.	3.275/hr.	3.97/hr.
10.	Machinist Maintenance A	4.193/hr.	3.505/hr.	3.76/hr.
	Salary Jobs			
11.	Drafting A	$172.51/wk.	$151.10/wk.	$163.95/wk
12.	Drafting B	150.69/wk.	125.00/wk.	137.85/wk
13.	Computer Operator A	158.88/wk.	---	158.88/wk
14.	Computer Operator B	138.05/wk.	112.93/wk.	129.67/wk
15.	Secretary	141.16/wk.	124.03/wk.	130.63/wk
16.	Steno-typist	122.11/wk.	95.75/wk.	110.04/wk
	Benefit Plans			
17.	Pension Plan	All 50%-100%	55%-100% 2 had none	
18.	Life Insurance - Sickness Accident	All 50%-100%	All 50%-100%	
19.	Hospitalization, Major Medical	All 50%-100%	50%-100% 1 had none	
20.	Supplemental Unemployment	Only 1 had	None	
21.	Tuition Refund	100% 1 had none	Up to 75-100% 2 had none	

Table 12

Comparative Rates for Job Classifications and Benefit Plans in Berkshire County

Source: Wage & Benefits Survey 1971 of Berkshire County, Association of Business & Commerce of Central Berkshire County, Inc.

labor. Also in item 8, the overall average is distorted downward by the intrusion of banks into job category. Under Benefit Plans, the notation indicates participation and the degree of company burden. For example, item 17, Pension Plan, indicates that all large plants had a plan and that the company portion of payments varied from 50% to 100% of the cost. Small plants bore 55% to 100% of the cost, but 2 of the small plants reporting had no plan at all. The evidence of Table 12 demonstrates the generally lower cost of labor and overhead elements to the small shop. Overlaps were noted in nearly every classification, however. Hourly employees were represented by unions in eight of the fifteen plants. The combination of lower labor costs, multiple application of workers to required tasks, and the lower benefit rates argue for lower relative expense making up the total costs C_c incurred in producing output for a period.

Competition among small shops is keen and, within a central technology, is strictly on a price basis. The price scale may be determined by the idle capacity of the shop. Pricing policy is often scaled to existing plant backlog. A four week backlog results in top scale prices providing the widest possible profit margin to the quoting shop and a good chance for competitors. A three week backlog dictates a price that is difficult for competition to meet or better, and a two week backlog results in a virtually noncompetitive low bid.[40]

A further survey within Berkshire County sought indications of probable market expansion for the small shop and purchase attitude

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[40] Personal Interviews, see Appendix D

on the part of large plants.[41] A small shop in Pittsfield achieved a business growth of 28% in sales over the last four years. Their first attempt at NC type machining occurred in the early 1960's and was not very successful. Machines of increasing sophistication were added in 1965, 1966, and 1967. Now 4 NC machines (20% of the machines in use) operate 18 hours per day each while the manuals operate only 9 hours each. Computer services are purchased from a nearby silk mill and tapes are internally programmed. The process of programming and use of both tapes and NC machines was self generated through the trade press, machine tool shows, and industry seminars. Use of machines, tapes, and methods is extremely good. Since 1967 some 6774 punched tapes have been generated and the economical lot size is a work plate with four cavities or more. This particular shop has experienced a continuing increase in business during 1971 although at a much lower rate than the three previous years. The policy on purchase of machines is present savings and liquidation of purchase cost through savings. Price of machines varied from $40,000 to $150,000 each. Machines are bought on the premise that their full life will be utilized, including rebuilding of worn features if justified. Emphasis is placed on purchasing machines of general capability which will last a long time. The shop is not, nor is it intended to be a high accuracy shop.

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[41] Personal Interviews, see Appendix D.

The question posed to large plant manufacturing managers was ''Do you foresee a reduction of manufacturing in your plant in favor of vendor manufacture? Your plant would continue to assemble.''

In the 1966-67 sample, response was threefold:

1. No such change will occur in the foreseeable future because of scale advantage of large shops and inherent reluctance to place orders for such work on vendors. The vendor problem is one of achieving uniform acceptable quality, and production schedule reliability.
2. The idea may be good in some respects, but small shops do not possess automated tools and are ''afraid'' of them from a maintenance aspect. Further they can neither develop nor purchase adequate, reliable service for such sophisticated machines and cannot cope with tape logistics if they could afford the tools and service.
3. The proposal is good and has a number of appeals, but will be prevented by union pressures against farmout in poor times and will require too many customer resources and too much time under good economic conditions. The large manufacturer would have to commit too much money and effort either on the tape - computer end or the quality assurance end to make the effort economical for him.

By 1971, however, significant changes appeared:

1. For the past five years, small shops have been acquiring numerically controlled machines very rapidly and their work quality is very good. The large customer would have

to retain developmental know-how and apply it to unique, expensive and/or difficult operations.

2. Small shop operation is attractive because the market is good and will get better and selective labor can provide desirable high quality output.
3. The small shop has a cost advantage because it is presently unattractive as a union or ‘‘cause’’ target.
4. Total costs whether direct or peripheral are moving against the limits of control. They are being pushed faster by the added distortions of higher rates of rise in the cost of government and services areas plus the correspondingly slower rate of rise of productivity in those areas. In addition, recent ill-conceived legislation and costly enforcement of such legislation is adding additional impetus to cost escalation. The large firm is most severely penalized. Vendor work is becoming more economically attractive in more and more areas.

Another question suggests itself when the small shop market is called attractive: who is being attracted to it? In Berkshire County, additional entrants to the field seem to be few. Some who were financially and technically capable of founding new ventures spent considerable effort to obtain detailed information, but did not make the move (at least on a full time basis) away from their present jobs. An aggressive approach was offered by a man currently responsible for a $14 million segment of a large plant's annual business. He has a desire to pursue such a venture either as a career change or as a retirement venture. His expectations were listed as follows:

''Automated tools run by paper tape. Computer linked to bank and/or customer plant.

''Expect one million dollar gross per year per location with employment per location at about 100 people.

''Would locate near employee rather than near customer and would employ retired and handicapped with only functional supervisors younger. Would also arrange shifts and hours to suit employees using 4 hour shifts starting and ending at off peak traffic periods.

''Because of tax drain, would solicit U. S. Senator and Representative help in securing SBA loan. Would expect to need about $10 million and plan 10 to 15 year pay off. Would utilize the conditions to get directed contracts to start.

''Believe smaller operators could tie to bank computers and banks should be interested in marketing such computer services.

''Big producers should be interested though it is contrary to accepted tradition. Also the computer-communication technology should provide the necessary simplified change control link.

''Would open new plant in new location if gross exceeded some empirical line ($1,250,000) rather than expand existing plant. Always would orient to retired people available.

''Transportation of goods is more efficient than transportation of employees. Would use company bus to pick-up and deliver employees.

"Would use customers' buying power for material and tool purchase advantages.

"Believe Massachusetts, and particularly Berkshire County, to be a very favorable area and also believe it is representative. Another suggested area is Sarasota, Florida".

Others felt advent would be slow, would be prevented by the technological advantage of the large enterprise, or was a good idea - for someone else first.[42]

Summary

Automating the job shop must be evaluated in terms of technology economy of output, cost and debt, labor, and market. The availability of technology, means to advance technology, and means to exploit technology have been rather conclusively demonstrated in several aspects:

1. Clopper Almon's forecast for the NMTBA
2. The history of NC computer assisted machines at shows through the last decade and examples of increasing sophistication.
3. Standardization techniques sponsored or encouraged by industry trade societies.
4. Development of "downstream" companies that support or embellish any capital goods industry.
5. The efforts and direction of industry giants in expanding application and development.

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[42] Personal Interviews, see Appendix D.

It appears that automation of the small job shop is mandatory when viewed against a set of critical concepts in order that the small shop remain competitive in the present market. Expansion of the small shop market through increasing the level of technology depends largely on the efforts of the individual establishment.

Economy is evident in terms of initial price as well as operating costs of NC machine tools. Reference to Figure 6 indicates that real prices are steadily more attractive. Available business indexes show a stability of machine tool prices greater than other segments of the economy. In addition, rate of yield on assets is enhanced by more advantageous depreciation allowances and availability of financing. By far the biggest advantage exists in the area of production cost. Savings in both scrap and output costs are really limited only by the material and tools and the ingenuity of the planners. For the small shop the difficulty tends to be one of transition rather than application or operation. More depends on the speed with which one man can acquire new expertise. While it may be true that in a small shop any one person knows more about the whole operation than in a large plant, the new machine techniques of programming, electronic maintenance, tool set up, and changed production scheduling lend themselves to parallel rather than sequential attack. That is to say, the small shop learning curve might be longer or the nominal yield rate on that stock of assets might be initially less than for the large shop. The absolute advantages of lower direct wage rates, overhead, and benefits are still effective.

Labor has been considered perfectly available. This assumption appears valid when viewed against current national employment levels and seems to hold locally despite the rate differentials apparent from Table 12.

The present market available to small shops appears to be greater then that presently being served based on the data in Table 11 and accompanying comments. Serving the indicated available market should prove attractive because it would not require a significant or proportional increase in fixed costs to furnish that magnitude of increased product output. This perhaps explains the apparent low attraction of the small shop to additional enterpreneurs, but it seems reasonable that as large manufacturers concentrate on large machines with broad capability, more business will be available in the general machining category for the small shop. The growth of this market is difficult to predict, but some indication of its increasing recognition is apparent from the Berkshire County surveys. In view of the recent large plant comments, the data of items 6 and 7 of Table 12 acquire a prophetic significance. The assembler category was more expensive to the small plant than to the large one and assembly rather than standard manufacture seems to be the present large plant trend. This certainly has occurred in the radio receiver market. If a similar shift is beginning in the producer goods market, the opportunity for the small shop is very great indeed.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The rapid technological advances of the nineteenth century led to adequate production of goods at prices within reach of most consumers for the first time in history. The major achievement was complete interchangeability of parts. This achievement depended on tools and processes capable of making components within tolerances which truly allowed random part selection in assembly of a product. Having accomplished interchangeability, the next step was processing in larger lots to lower unit costs. Expanded markets resulted in growing factories, growing towns, and a fundamental shift from agriculture as the major U. S. occupation.

With the advent of the electric motor, tools became more versatile, more complex, and the shift in skill from man to machine began. Increasingly sensitive automatic machines replaced man as manufacturers. In the attempt to respond competitively to increased demand for a wider variety of models, successful efforts developed automatic manufacture for standard items and flexible fast response machines for families of models. The combination of the computer and the tape controlled machine tool in recent years provided an extremely versatile production resource not previously available. This new resource raised immediate questions as to its best application. At the same time, other challenges such as industrial concentration, plant size, and general business regulation became significant.

Application of NC machines. Appropriate use of scientific analysis plus manufacturing experience first disclosed when not to use NC machines. Large quantities of identical parts lent themselves to the latest techniques in hard tooling including automatic manufacture. Such things as screws, lamp bulbs, radio tubes are obvious examples. In addition, the examples given in Chapter II of motors and transformers indicated standardization of parts not immediately obvious in the traditional job shop environment.

The suggested criteria, listed in Chapter II, for economical application of NC machines may be broadly grouped as:

a) Expensive material or costly scrap and rejects

b) Frequent design changes

c) High complexity of task or set-up

d) Space consuming inventory

e) Families of parts having similar but not identical machine operations

Comparison of several kinds of products demonstrates the usefulness of these major criteria. The aircraft engine industry fits all five categories and owns the most NC machines. Product groups such as lamps, radio tubes, and general purpose control could possibly be classed under (e) and have very few NC machines though they put considerable emphasis on automatic manufacture.

At least three of the five categories can be applied to the market served by the small job shop which should then logically have a strong interest in NC machine applications. There is evidence of such interest particularly since 1965-66 when major advancements were made in peripheral technology such as standardization of machine motions, availability of general software and ‘‘canned programs’’ for machine functions, and machine maintainability. The small shop can also achieve a successful competitive position as skills and quality become more dependent on the machine.

Limitations. Large plant limitations seem to center on items not directly involving production of goods such as:

antitrust

taxes

labor costs

motivation-communication

research and development

Small plant limitations tend to be more nearly product oriented such as:

money

state of technology

marketing

Large plant limitations seem to be associated in many cases with taxing the capacity of the community to provide services. The efficiencies of operation which contributed to growth have now created a target for non-production related inspection. Though there is little argument with the need for regulation, the posture of both the Justice Department and the FTC has suggested that bigness per se is considered objectionable. The increase in property taxes and portion of total tax paid to the community plus burdens of such things as pollution control, unemployment taxes, and federal safety, employment, and opportunity reports are much more costly to large firms than small. This cost is reflected in overhead rates and other indirect costs.

Labor costs in terms of benefits, training, and direct hourly rates are higher for the large plant. In addition, there appears to be some optimum relative plant size - employment - supervision ratio below which employees do not feel the need for organized representation nor is worker productivity a problem. Several elements seem to exist such as newness of plant and employees, numbers up to the point where treatment as groups begins to irritate personal sensibilities, and the imposition of uniform rules irrespective of judgment. It is not the function of this paper to do more than observe such conditions and to note the efforts of Chrysler, General Electric, and Lockheed to increase the job involvement of workers. The large company concern witnesses to both the existence and cost of the attitude.

The research and development which is necessary and possible only to the large plant is listed here as a limitation because of its inherent inefficiency. A one to five ratio of products produced from those entering development is common. That is, for fifteen potential products moving from research into deveopment, only two or three will become marketable products in three to four years' time. Spin-offs are not always successful as a means of supporting the original development. Anocut Engineering Company, mentioned as a Lockheed spin-off for spark sintering processes, was recently reported in financial difficulty. The research and similar added costs for the large plant contribute to its competitive position as long as they improve its technological leadership and worker productivity.

The small plant tends to have difficulty getting money both in payment from customers and from lending sources. This difficulty adversely affects the debt - equity ratio which can have a critical effect on the price of liabilities. Technological and marketing limitations are often interdependent to some extent. The volume of work in particular types of tasks requires multi-functional application of workers at all levels. This required multi-functional responsiblity becomes a disadvantage when special concentration is required to improve the firm's technological state or to expand markets. Any delay in improving technology or securing new customers can in turn increase the difficulties of securing funds for capital needs. One of the important balances needed is the encouragement of multi-functional cooperation while discouraging cross-functional interference.

Opportunities. The small plant cannot compete head-to-head with the large one in unit production costs, technology, or development. Competition must be selective in order to favor those segments of production where the competitive advantage of the large plant is minimized or overcome. Such situations occur when:

a) Only limited numbers of similar parts are required

b) When parts to be produced require a state of technology widely existant

c) When required parts are of a family of universal demand

d) When quick response, minimum specifications, or frequent minor design changes are necessary or likely.

Each item is an NC machine requirement and the small shop can successfully compete because

a) Limited quantity eliminates large shop volume efficiencies

b) Standard technology favors price-only competition

c) Universal demand improves market span and reduces risk of acquiring a ''white elephant'' machine.

The point is easily demonstrated if several examples of large quantity production are examined. Items selected were perfumes, crude oil, butter, electricity. After initial examination, perfumes were eliminated because they are highly responsive to advertising while heavy industrial products are relatively inert.[1] Tables 13, 14, and 15 give comparative costs and volumes for the remaining items. These products are outputs of continuous processes in the case of crude oil and electricity and of high volume discrete units in the case of butter.

COST OF MANUFACTURING A POUND OF BUTTER AT 78 CREAMERIES IN THE PRAIRIE PROVINCES

Production (000) lb.	Up to 100	100 199	200 299	300 399	400 499	500 and up
No. of Creameries	4	14	22	19	5	14
Cost in cents	4.82	3.89	3.52	3.62	3.37	3.18

TABLE 13

Source: Department of Agriculture Dominion of Canada Technical Bulletin No. 13 An Economic Analysis of Creamery Operations in Manitoba, Saskatchewan and Alberta 1938.

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[1] Dean, Joel, and Joel Dean Associates, Managerial Economics, pp 351-393

SIZE OF REFINERY AND COST OF CRUDE OIL PRODUCTION

Geographic Area	Midwest	Gulf States	Chicago
Capacity of Refinery in barrels of crude per day	5,000	15,000	60,000
Capital Investment	$2,000,000	$5,000,000	$16,000,000
Total cost per barrel	$1.529	$1.667	$1.757

TABLE 14

Source: Testimony of Robert E. Wilson (Pan American Petroleum and Transportation Company) Hearing before the Temporary National Economic Commission Part 15, Petroleum Industry Section II pp 8636-8637, 1939.

Note: Cost for Gulf States and Chicago are distorted upward by pipeline transportation rates of $0.125 and $0.345 respectively.

RELATIONSHIP OF COST PER KWH TO EFFECTIVE CAPACITY OF POWER PLANT

Size Effective Capacity KW	Cost Cents per KWH
800	3.2
2000	2.2
4000	1.7
8000	1.7
20000	1.4
35000	.98
50000	.85
110000	.79

TABLE 15

Source: U. S. Geological Survey Professional Paper No. 123, 1921.

Note: Figures are adjusted to price of a ''standard'' ton of coal at $5.35.

While each high volume product shows some sort of plateau or break point (true of oil when adjusted for transportation charges) over the range, there is no doubt that as production of units goes up, cost per unit comes down. Per unit cost is a function of quantity as stated in equation (4), Chapter IV. The pertinent point is that small shop opportunity occurs when the quantity per customer is limited and where the technology required to produce the part is general. Then the large plant has no advantages of technique or know-how. Under these circumstances, the small shop is cheaper as shown in Chapter IV, Table 12. It has also been demonstrated that in a small local sample, qualified people were willing to accept long term employment in small shops and others were willing to undertake their direction.

The large plant will unquestionably dominate those areas where large capital investment is required and where exotic materials are worked. Also, the large plant will retain its volume efficiencies and be able to achieve low per unit cost in the areas of batch handling, assembly, and associated procedures.

Conclusions

Job shop automation will continue to expand along two major lines:

a) The low quantity, expensive material, advanced technology products such as jet or rocket engines, turbines, and gears.

b) The tailored model products of similar but not the same machined parts and various types of industrial controls.

In both cases, degree of application will be governed by the technology required to make the product and economic lot size of components.

Application of central computer control over several remote machines is now possible. At least in the near term, this application appears limited to process control functions and to those areas where significant reduction in transfer time from machine to machine can be achieved. Molins Machine Co., Ltd. offered their ''System 24'' in 1967 which linked seven machine tools together and controlled the system from a single computer. Its objective was to handle job lots of up to 3000 parts per day on a basis which would eliminate the need for human transfer and set up between individual NC machines.[2] The tremendous versatility of the computer would seem to mitigate against centralized remote control except for limited systems. Applications of computers are much broader than applications of machine tools. The need for post processors to overcome machine model idiosyncrasies would argue for manipulating tapes rather than incurring the additional cost of machine-computer modification. Finally, when the operating time of a computer is compared to the operating time of a machine tool, it seems inefficient to dedicate the computer to the machines. Some type of time sharing feature would, no doubt, be warranted. The excess computer time could be devoted to other plant functions.

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[2] Plant Computers Try for Promotion, Business Week, June 29, 1968

The biggest growth sector seems to be the small shop. The particular example given in Chapter IV shows a market 6% to 13% larger for small business. Another small plant increased its business about 28% in four years. To this is added the increased vendor share of Chrysler and General Electric. It may be argued that large customers victimize small shops by letting out only low margin, difficult jobs. In certain instances this may be true and it may partly account for the small shop failure to bid in the example given. The evidence of the rates in Berkshire County (Table 12) supports the view that on limited lot sizes requiring standard or generally available technology, the small shop cost averages distinctly lower in both labor and overhead categories. Such rates are not dependent on low margin, difficult jobs. The task facing the small shop is to be able to price its output below the large shop cost. Comparing direct labor rates from Table 12 shows the small shop having an advantage of 3.7% on unweighted average rates. If profit on industrial sales is estimated at 7% and consideration is given to lower overhead for the small shop, the challenge appears quite reasonable.

The large plants are being forced to look at their own costs more closely by the marketplace competition and public policy. The resulting profit shortfall was examined in Chapter III. There is little evidence that the size of corporations will diminish, but there is evidence that current public policy will limit growth and that purchase of more components is an alternative to give some relief to the rapidly mounting direct and peripheral costs. Advantages to the large plant are:

a) Reduction in area employment

b) Reduction of physical plant and therefore property taxes.

c) Reduction of labor functions to allow concentration on only those functions that a large plant does best, e.g. assembly.

Large corporations have attempted to gain these advantages by decentralizing, but union pattern bargaining and similar attentions have largely minimized gains after the initial local tax and capital equipment options have been exercised.

The key to small shop success appears to be twofold:

a) More efficient acquisition of technology

b) Better total marketing

The small shop can seldom pioneer technology. For its success, it must rely on better acquisition of existing technology and more rapid exploitation of it. Many small shops guard their expertise jealously. There is serious question as to whether or not they are guarding anything at all unique. It would seem more advantageous to them to pool resources in some fashion so that their rate of acquiring existing technology would increase. Means appear to be more readily available now. A number of states have established technological aid to industry through the state university systems. Programs are established in South Carolina, Minnesota, Massachusetts, Illinois, Ohio, Michigan, Wisconsin, Iowa, and Indiana. The purpose is to provide to state industry a service similar to the agricultural extension service. Results in many states have been impressive. In Massachusetts, the Commonwealth Technical Resource Service administered by the University of Massachusetts under the State Technical Services Act of 1965 attempts to enlist major institutions of learning within the state in sponsoring qualified projects for investigation. The overall method is very similar to programs in other states where three main channels of communication are maintained; carrying out approved technological projects for the benefit of a state industry, conducting seminars to publicize the service and state of the art, and responding to individual calls for assistance. It has been suggested that the technology development needed by the small shop, which can now acquire, operate and support sophisticated tools, be supplied by a trade guild organized for the purpose of pooling information and perhaps certain service functions. This type of organization has been successful in Europe.

With the above avenues opening, additional support could be expected from existing trade journals. A stronger trade organization can focus more attention on the marketing aspect of the business. As M&M discovered, business improved with uniform, faster costing and quoting. Better business methods were a significant complement to product quality and delivery. Here again is demonstrated the advantage of acquiring an existing technique for use by the small shop.

The market available to the small shop seems to be larger than that presently served. If so, the small shop could acquire the rest of the market by improving its own efficiency. Degree of improvement depends on skill of exploitation. To exploit the market will take some investment by the shop in money, in innovation, and in willingness to pool resources appropriately. How much a shop should invest in such an effort, what types of tools should be added, and in which functional area the primary effort should be made are questions which can only be resolved after careful analysis of individual situations.

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APPENDIX

APPENDIX

Appendix A

Available Computer Programs and Their Major Features

There are at least six computer programs for writing tape instructions that direct N. C. point-to-point machine tools.

1. AUTOPROPS (Automatic Program for Positioning System) is a two (2) axis program developed by IBM and Pratt and Whitney for the IBM 1401 computer. It makes extensive use of abbreviations of hole patterns, so that matrices and bolt circles can be programmed with only a few simple statements.
2. AUTOSPOT (Automatic System for Positioning Tools) is a three (3) axis program with limited four (4) axis capability. It was developed for the K&T Milwaukeematic for use on the IBM 1620 computer.
3. CAMP I (Compiler for Automatic Machine Programming) is a three (3) axis program. It was written by Westinghouse for GPE's LGP-30 computer.
4. CAMP II is a 2-5 axis program written by Westinghouse and IBM for the 7094 and 7090 computers. AUTOSPOT as mentioned earlier, is actually a condensed version of CAMP II.
5. PRONTO (Program for Numerical Tools) is a three-axis program written originally by Manufacturing Engineering Services of the General Electric Company for the IBM 704 and 7090 computers. It was subsequently rewritten by GE's Computer Department for the GE-225 computer.

There is a separate computer program, available as an option to be used with PRONTO on the GE-225. This is a machinability package that calculates the metal-removal rate from tool geometry, the type of material (both tool and workpiece), the surface finishes desired, and the given machine-tool characteristics (horsepower limitation and the like). After extensive field testing, this program is now available.

A generalized postprocessor has been written for the PRONTO program, following the format of the Electronics Industries Association wherever possible. Complete in generalized form, this postprocessor requires only the addition of tables of characteristics for the machine tool and control system that will be used. In 1964, completed postprocessors were available for Burgmaster drills and the Wiedemann turret punch press (both with GE Mark II controls). Other postprocessors were being developed for the Milwaukeematic, a Giddings and Lewis three-axis boring mill, and a Lucas three-axis boring mill (all with GE Mark II controls), as well as the Burgmaster and Cleereman Spindlemaster drills with GE Mark Century three-axis controls.

6. SNAP (Simplified Numerical Automatic Programmer) is a two (2) axis program written for the Brown and Sharp turret drill and IBM 1401 computer.

The best known contour programs will be described briefly:

1. ADAPT (Air Material Command Developed APT) is a three-axis continuous path program written by IBM under Air Force contract. It is a general processing type of program written for small to medium size computers.

ADAPT has complete two-dimensional capability in the X-Y plane, and limited third axis capability. It can do simple copy logic such as copying a line of holes, as well as macros - a group of instructions that are repeated such as the sequence of instructions required to drill one hole.

2. APT (Automatically Programmed Tools) is a multi-axis contouring program that grew out of a contract sponsored by the Air Force and with the MIT Servo-mechanism Laboratory. More than 100 man years of effort, spread out over 20 cooperating companies in the aerospace industry went into developing the program. This APT program is the most widely used, recommended and copied and is adopted for use only on a large computer.

3. AUTOMAP (Automatic Machining Program) is a two-axis continuous path contouring program for arcs and slopes plus third axis positioning but not simultaneously with the first two. Written for the IBM 1620 computer it has a language of about 40 words from the APT language.

4. AUTOPROMT (Automatic Programmed Tools) is a contouring program written by IBM for its 7090 computer. It is similar to the APT program and plans call for the integration of AUTOPROMT into the APT system by IIT Research Institute. AUTOPROMT is a more sophisticated program than APT, and the programmer need only define the part geometry and the boundaries of those regions where the cutter must make multiple passes to remove pockets and the like. The computer then

calculates what path the tool must follow to remove material most efficiently. In APT the programmer must define the complete path the cutter is to follow, including additional steps necessary to remove excess material in pockets or similar large areas.

5. SPLIT (Sundstrand Processing Language Internally Translated) is a multi-axis continuous path program written by Sundstrand for the IBM 7090, 1620 and 650 computers. Oriented toward a specific machine, it requires no postprocessor and only one pass through the computer. SPLIT has the ability to handle macro instructions or canned cycles for drilling, deep hole drilling, boring and tapping.

Appendix B

Accumulation of Assets and Companies Merging most Frequently

Acquisitions of Manufacturing and Mining Companies with assets of more than $150 million 1962-1967

Acquiring Company	Acquisition	Year	Asset value of Acquisition Millions of dollars
Union Oil	Pure Oil	1965	$766.1
McDonnell	Douglas Aircraft	1967	564.7
Continental Oil	Consolidation Coal	1966	466.1
Atlantic Refining	Richfield Oil	1966	449.7
North American Aviation	Rockwell-Standard	1967	391.2
U.S. Plywood	Champion Papers	1967	335.3
FMC	American Viscose	1967	334.8
Signal Oil & Gas	Mack Trucks	1967	303.0
Studebaker	Worthington	1967	296.6
General Telephone & Electronics	Sylvania Electric	1959	264.9
Tenneco	Kern County Land	1967	253.9
American-Marietta	Martin	1961	246.6
Mathieson Chemical	Olin Industries	1954	232.5
Ford Motor	Philco	1961	231.9
Sperry	Remington Rand	1955	207.7
SCM	Glidden	1967	198.7
Ling-Temco-Vought	Wilson	1967	196.2
Sunray Oil	Mid-Continent Oil	1955	186.3
Diamond Alkali	Shamrock Oil & Gas	1967	173.7
American Can	Marathon	1957	168.9
Kern County Land	J. I. Case	1964	168.7
El Paso Natural Gas	Beaunit	1967	166.4
Gulf Oil	Warren Petroleum	1956	163.9
Glen Alden	Stanley Warner	1967	157.3
Philadelphia & Reading	Lone Star Steel	1965	156.0
Armco Steel	National Supply	1958	155.7
Allied Chemical	Union Texas Natural Gas	1962	154.1
Dresser Industries	Harbison-Walker	1967	151.0

Data: Federal Trade Commission

TABLE 16

Companies Doing the Most Merging
1962 - 1967

	Year	Assets acquired Millions of dollars
FMC		
American Viscose	1963	$334.8
Link-Belt	1967	144.0
Tenneco		
Heyden Newport Chemical	1963	66.4
Wilcox Oil	1964	13.7
Delhi Taylor Oil (50%)	1964	52.4
California Ink	1964	10.6
Cary Chemicals	1965	27.6
Packing Corp. of America	1965	126.5
Nixon Baldwin Chemicals	1966	13.3
General Foam	1967	13.6
Kern County Land	1967	253.9
Atlantic Richfield		
Nuclear Materials	1964	11.8
Richfield Oil	1966	449.7
Studebaker		
Wagner Electric	1967	78.6
Worthington	1967	296.6
Glen Alden		
BVD	1966	113.2
Stanley Warner	1967	157.3
Philip Carey	1967	64.8
Gulf & Western		
Miller Mfg.	1964	10.0
New Jersey Zinc	1964	143.0
North & Judd	1967	11.7
South Puerto Rico Sugar	1967	122.1
Ling-Temco-Vought		
Wilson & Co.	1967	196.2
Memcor	1967	12.9

(Table continued on page 129)

	Year	Assets acquired Millions of dollars
Litton		
Fitchburg Paper	1964	$ 13.9
Hewitt-Robins	1965	48.5
Royal McBee	1965	70.1
American Book	1967	24.4
Jefferson Electric	1967	12.7
Louis Allis	1967	34.1
Ashland Oil		
United Carbon	1963	89.3
Catalin	1966	10.6
Warren Bros.	1966	38.7
Archer-Daniels-Midland (partial)	1967	50.0
Celanese		
Champlin Oil & Refining	1964	142.4
Devoe & Raynolds	1964	44.5
Georgia-Pacific		
Puget Sound Pulp	1963	66.0
St. Croix Paper	1963	29.4
Bestwall Gypsum	1965	63.9
Kalamazoo Paper	1967	23.4
Sinclair Oil		
Drilling & Exploration	1963	19.5
Western Natural Gas	1963	76.4
Texas Gulf Products	1964	69.7
Barber Oil (partial)	1966	11.6
Hunt Foods		
Knox Glass	1965	27.0
McCall	1967	149.2
International Telepone & Telegraph		
Bell & Gossett	1963	26.9
Cannon Electric	1963	29.7
General Controls	1963	32.4
John J. Nesbitt	1963	12.9
Gilfillan	1964	14.5
Howard W. Sams	1966	19.5
Jasper Blackburn	1967	10.6

(Table continued on page 130)

	Year	Assets acquired Millions of dollars
Textron		
Parkersburg Aetna	1963	$ 17.0
Jones & Lamson	1964	14.5
Sheaffer Pen	1966	25.0
Bostitch	1966	37.4
Gorham	1967	31.1

Data: Federal Trade Commission

TABLE 17

Appendix C

Concentration of NC Machines within General Electric Company, March 1970

Concentration of NC Machines within General Electric Co.

Business Segment	Number	On Order
Aircraft Engines	213	12
Motors	88	0
Control	79	2
Military Systems	63	0
Turbines	51	11
Other		
Processor Equipment	16	1
Ballast	14	0
Reactor & Fuels Mfg. Opn.	13	0
Transportation Equipment Products	12	0

Data Source: Manufacturing Engineering Operations, General Electric Company

TABLE 18

Note: Departments are grouped under business headings and only those locations having twelve or more machines installed were included.

Appendix D

Personal Interviews

Personal Interviews covered a wide range of sources including responsible management representatives of large and small firms, employees of both large and small firms, and representatives of related social, educational, and government organizations.

General Electric Company

Mr. W. A. Copley, Mgr. General Books, Specialty Control Dept.

Mr. R. E. Dougherty, Specialist, Relations and Utilities, Schenectady Works

Mr. J. M. Hoylman, Quality Control Specialist, Specialty Control

Mr. C. T. Humphrey, Mgr. Marketing, Communications and Control Dept.

Mr. William Karlon, Advanced Mfg. Eng., Ordnance Dept.

Mr. C. T. Morin, Mgr. Tool Engineering, Ordnance Dept.

Mr. J. W. Ostresh, Planner, Distribution Transformer Dept.

Mr. J. E. Russett, Mgr. Advanced Mfg. Eng., Ordnance Dept.

Mr. P. W. Sherman, Relations and Utilities - Power Transformer Dept.

Mr. L. J. Stolzberg, Mgr. Materials, Ordnance Dept.

Mr. P. L. Williams, Program Manager - Training Systems, Ordnance Dept.

Other Organizations

Mr. A. A. Bogdan, Executive Director, The Urban Coalition, Pittsfield, Mass.

Dr. Geoffrey Boothroyd, Department of Mechanical and Aerospace Engineering, University of Massachusetts

Mr. Harold Brunton, Dean of Administration, University of South Carolina, Columbia, S. C.

Other Organizations (cont'd)

Mr. W. M. Childs, Sales and Estimating, Monroe Forge Company, Rochester, N. Y.

Mr. Simon England, England's Department Store, Pittsfield, Massachusetts

Mr. P. W. Ferland, President, Marland Mold Co., Inc. Pittsfield, Mass.

Mr. S. R. Giansiracusa, Vehicle Maintenance, Cresent Creamery, Pittsfield, Mass.

Mr. J. W. Kapitan, Commonwealth Technical Resources Services.

Mr. D. W. Lundy, Mgr., Mold Frame Dept., Marland Mold Co., Inc. Pittsfield, Mass.

Mr. W. N. Vercoe, Ass't Director for Conference Services, Division of Continuing Education, University of Mass.

Mr. K. A. Vosburgh, owner, Ken's Auto Upholstery, Pittsfield, Mass.